The

Tropical Agriculturist

January 1930

EDITORIAL

SOIL ORGANIC MATTER AND GREEN MANURING

IN a recent number of the *Journal of the American Society of Agronomy* there is published a series of articles on soil organic matter and green manuring problems by some of the leading agronomists and soil workers in America. The papers relate primarily to the soil and agricultural conditions of that country, but, as some of the points raised in them have a bearing on Ceylon agriculture, they may be briefly referred to.

General observation and the limited work done in Ceylon on the relation between soil type and organic matter content appears to confirm Marbut's finding that, in general, the profiles of semi-tropical and tropical soil types show a very rapid rate of decrease of organic matter with depth. In his paper on organic matter problems in humid soils, Lyon discusses the question of the occasional loss of soil nitrogen which is not traceable to removal in crops or drainage water. He concludes that soil tillage, absence of plant growth, high nitrogen content of a soil and the application of large quantities of nitrogenous manures favour a large loss of this kind. Some of these conclusions have an important relation to agricultural practice in the wet regions of Ceylon. On tea estates heavy nitrogenous manuring is not uncommon, and it may well be asked how much of the nitrogen added in manures is utilised by the crop and how much lost through denitrification and leaching. The results of investigations at Peradeniya indicate that losses through leaching are small on cropped land. Denitrification losses would appear to be more serious and deserve investigation. Lyon enquires whether, in view of losses through denitrification, mineral fertilisers should not be substituted for part of the organic manures used and whether other important uses cannot be found for green manure legume crops. In contrast to cultivated soils, uncultivated land under grass or weeds loses little or no organic matter and nitrogen. In fact, such land tends to become richer in these constituents. There may here be a reason why grass-covered coconut lands continue to give good yields of nuts in Ceylon.

Russell's contribution on organic matter problems under dry-land conditions raises issues of some importance in Ceylon. The depletion of soil organic matter which is rapid under these conditions has produced profound detrimental changes in soil structure and tilth, and soil drifting has become a serious problem. Under Ceylon dry-land conditions the latter phenomenon would probably give place to soil erosion, as heavy rains generally follow long periods of drought. In the arid regions of America where the rainfall is often less than twenty inches per annum, the growing of a green manure crop for improvement of the organic matter of the soil is not recommended. Fortunately for Ceylon it has no area with rainfall conditions comparable to those of the dry lands referred to. Most parts of the island could adopt with advantage a judicious system of green manuring as a partial solution to the organic matter problem of these districts. The application of straw along with artificial nitrogenous manures would also be helpful.

Burgess' paper deals with organic matter problems in relation to irrigated soils. The irrigation conditions of arid regions are similar to those obtaining in the Jaffna Peninsula. Although the organic matter and nitrogen contents of arid soils are very low, citrus plantations in these regions give remarkably good yields. Manuring with cattle manure has been found advantageous, but green manuring has not always proved as economical as the former. The value of cattle manure for irrigated crops is appreciated in Jaffna. Greaves supplies experimental evidence to show that losses of organic matter in arid districts are not much greater from heavily-manured than from lightly-manured soils. Waksman discusses the principles underlying the decomposition of green manures in the soil. The advantages of using young plant material in preference to mature plants and plant residues for green manuring are clearly indicated. The last paper is one by Pieters and McKee on green manuring and its application to agricultural practices. Of particular interest to Ceylon agriculturists is the knowledge of the use of green manures on citrus plantations in arid and semi-arid regions where they have been found to be the most economical means of insuring the production of first-quality fruit in quantity. The advantages of using permanent leguminous crops in orchards in the more humid areas have also been clearly demonstrated. The establishment of covers on rubber and coconut estates in the wetter regions of Ceylon may be expected to give equally beneficial results.

The present number of this journal contains two articles on green manures and cover crops in relation to the moisture, nitrogen and carbon contents and the reaction of the soils on which they are grown. It has been demonstrated that with suitable treatment green manures and cover crops can maintain and even increase the soil moisture content during periods of drought. It also appears that the carbon and nitrogen content of soils can be maintained at least at the original level.

ORIGINAL ARTICLES.

THE EFFECTS OF GREEN MANURES AND COVER CROPS ON SOIL MOISTURE.

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IN *The Tropical Agriculturist* of November 1927* the results of preliminary work at Peradeniya on the relation of cover crops to soil moisture were published. It was shown that more moisture was lost from soils under cover crops in the early stages of their growth than from the control during a period of drought and that the reverse was the case when the cover crop had been established for a longer period. The question of the moisture content of soils in relation to the growth of green manures is one of some importance not only in dry districts but also in those areas which, though having adequate annual precipitation, experience droughts of long duration at certain times of the year. It has been urged that during periods of long-continued drought green manure crops would compete with the main crop for the soil moisture to such an extent that the latter would often be adversely affected. In order to ascertain to what extent green manures affected the moisture content of soils during drought, a series of moisture determinations was carried out on soil samples taken at different depths up to 24 inches from the permanent green manure and cover crop plots on the Experiment Station, Peradeniya, at the end of periods of drought during 1928 and 1929. The cover crop plots were included in the series in order to ascertain whether the previous results obtained would be confirmed. The soil samples were taken from adjacent plots in each of three blocks of plots treated as follows:

A. *Tree plots.*—(1) *Gliricidia* unlopped, (2) *Gliricidia* periodically lopped and loppings envelope-forked into the soil, (3) dadap unlopped, (4) dadap lopped as in (2), (5) control.

B. *Bush plots.*—(1) *Tephrosia candida* (boga) unlopped, (2) *Tephrosia candida* lopped as in A (2), (3) *Crotalaria anagyroides* unlopped, (4) *Crotalaria anagyroides* as in A (2), (5) control.

* Cover crops at Peradeniya in relation to soil moisture. Vol. LXIX, No. 5, Nov. 1927.

C. *Cover plots.*—(1) *Dolichos hosei* (Vigna) uncut, (2) *Dolichos hosei* cut as in A (2), (3) *Indigofera endecaphylla* uncut, (4) *Indigofera endecaphylla* cut as in A (2), (5) control.

The green manures and cover crops were planted out in late 1926 and early 1927. The green manures in two of the plots in each block were lopped or cut and the green material was envelope-forked into the soil. The green manures in two other plots were uncut and one plot was left as control. It was therefore possible to ascertain how green manures treated differently would affect the moisture content of soils. The bush green manure plots were the first to be lopped with the result that the *Crotalaria* plots had to be replanted in June 1928. No weights of loppings or green material were recorded. In the case of the loppings from the tree green manure plots, both leaves and stems were forked in. The results of the tree, bush and creeper plots will be separately considered as the different blocks of plots were at some distance apart.

THE TREE PLOTS.

These plots were first sampled on the 24th February 1928 at the end of a drought of thirteen days. The trees had just begun to grow vigorously. The last forking of the lopped plots was done on the 17th December 1927 and, as the rainfall in the interval was 12·55 inches, the loppings were well decomposed. The results of moisture determinations are shown in table I below.

Table I.

Per cent. moisture on soil at 100°C.

Depth.	*Gliricidia* unlopped.	*Gliricidia* lopped.	Dadap unlopped.	Dadap lopped.	Control.
0- 3 in.	9·43	10·30	10·34	11·53	9·49
3- 6 in.	13·24	16·43	14·09	16·89	15·40
6-12 in.	15·81	23·91	20·04	21·11	20·94
12-24 in.	23·16	28·42	24·41	23·36	23·99

An examination of this table shows that (1) the plots in which the loppings had been buried had more moisture than the corresponding unlopped plots and the control at nearly all depths up to 24 inches. The *Gliricidia* lopped plots had more moisture than the corresponding dadap plots due doubtless to the much larger yields of green material supplied by the *Gliricidia* trees. As the green material was comparatively young and had sufficient time to decompose in the soil, the humus formed increased the moisture-retaining capacity of the soil; (2) the unlopped plots had, as was to be expected, less moisture than the control at nearly all depths. This is due to transpiration from the leaves and the trees not being old enough to exert any shade effect on the soil. The *Gliricidia* unlopped plot had less moisture at all depths than the corresponding dadap plot owing to the much better growth of the *Gliricidia* trees.

These plots were sampled again on the 22nd January 1929 and a further sampling was taken a month later. The plots were last lopped on the 28th December 1928 and the incidence of rainfall in the interval was as follows: ·85 inches on January 7th, ·09 inches on the 29th, and ·11 inches on February 7th 1929. It will be noted that the drought was fairly severe, only 1·05 inches having fallen during two months. The loppings in the forked plots had, as a consequence, remained undecomposed leaving large air spaces in the soil. The Gliricidia in the unlopped plots had made very good growth and afforded heavy shade. The dadaps on the other hand had not done well and the shade they afforded was poor. The results of the soil moisture determinations are shown in table II below.

Table II.

Per cent. moisture on soil at 100°C.

Date of sampling 22-1-29.

Depth.	*Gliricidia* unlopped.	*Gliricidia* lopped.	Dadap unlopped.	Dadap lopped.	Control.
0- 3 in.	12·64	13·03	12·33	13·33	11·40
3- 6 in.	21·07	19·85	19·20	22·73	18·68
6-12 in.	26·34	24·79	22·90	24·71	23·67
12-24 in.	29·82	25·99	27·05	26·75	25·79
		Date of sampling 22-2-29.			
0- 3 in.	9·52	8·03	8·60	8·27	9·51
3- 6 in.	14·06	12·96	12·69	12·36	13·18
6-12 in.	18·06	16·87	17·07	18·18	18·37
12-24 in.	20·85	21·96	22·48	21·76	22·12

On examining these figures it will be noted that (1) in the early stages of the drought the soils from the green manure plots had more moisture than the control at all depths in spite of transpiration from the leaves. At the end of a longer period of drought, however, the moisture contents of the soils of the green manure plots were slightly less than those of the control; (2) the *Gliricidia* unlopped plot had more moisture than the lopped plots at nearly all depths, both during the early and the later stages of the drought. This would seem to indicate that the shade effect of the Gliricidias more than compensated for the loss of moisture by transpiration through the leaves and that the turning in of green material, as in this case, when rainfall conditions were unsatisfactory for its decomposition in the soil, would result in greater losses of soil moisture than if the green material was left unlopped, especially if the amounts of green loppings are large; (3) the unlopped dadap plot had less moisture at all but the lowest depth than the corresponding lopped plot at the beginning of the drought owing probably to the transpiration from the leaves being greater than the shade effect of the dadap trees.

Moisture determinations were also made on soil samples taken from a set of tree plots not identical with the former on the 14th September 1929 after a period of fairly severe drought. Only 1·6 inches of rain had fallen during August in slight showers and a total of ·56 inches on the 1st and 5th of September. In this set of plots the growth of dadaps in the unlopped plot was particularly good. The loppings were last forked into the soil on June 1st 1929 and had been fairly well decomposed at the time of soil sampling. Table III shows the results obtained.

Table III.

Per cent. moisture on soil at 100°C.

Depth.	*Gliricidia* unlopped.	*Gliricidia* lopped.	Dadap unlopped.	Dadap lopped.	Control.
0- 3 in.	9·03	6·72	10·12	6·91	8·61
3- 6 in.	11·14	10·00	13·82	10·01	13·63
6-12 in.	14·31	14·15	17·45	14·03	18·92
12-24 in.	16·35	17·52	20·28	16·70	21·83

In this instance it will be seen that (1) the unlopped plots had more moisture than the lopped plots at nearly all depths. This is doubtless due to the shade effect of the trees. The dadap unlopped plot had more soil moisture than the corresponding *Gliricidia* plot. The moisture contents of soils under green manure trees is obviously dependent on the growths of the latter in these soils and is the resultant of losses due to transpiration from the leaves on the one hand and the gains due to the shade afforded by them on the other; (2) the control plot had the greatest amounts of moisture. This confirms what was found previously, viz., that, if the drought is severe and prolonged, there may be greater losses of moisture from the green manure tree plots than from the control. The trees in all the lopped plots had at the time of sampling grown to some extent but their shade effect was inappreciable. Losses of moisture by transpiration from these plots were therefore apparently great and evidently more than counterbalanced the amounts of moisture retained by the decomposed organic matter.

On the whole the above results would appear to point to the importance of (1) the shade effect of tree green manures in preventing losses of moisture directly from the soil through evaporation, (2) the time of burying green manures. Previous work carried out indicates that green manures should be turned into the soil during showery weather towards the end of the rains when an alternation of rain and dry weather occurs. This will encourage speedy decomposition of the green manures in the soil and hence the retention of moisture by the humus formed as a result of the decomposition. Green manures should not be turned into the soil either before or during a drought, as owing to

the dry weather the materials remain undecomposed leaving large air spaces that cause loss of moisture by evaporation. If for some reason green manures cannot be turned into the soil, especially in dry districts, at the proper time they should be cut and left as a mulch on the surface of the soil, unless of course the shade afforded is so great that it would counterbalance any losses of moisture by transpiration and direct evaporation from the soil. In any case this would apply only to tree green manures.

THE BUSH PLOTS.

Moisture determinations were made on soil samples taken from these plots on the 22nd June 1929. The results are shown in table IV below. The green manure bushes in the lopped plots were last turned into the soil on the 1st January 1929, so that there was sufficient time for the loppings to decompose in the soil before the soil sampling was made.

Table IV.

Per cent. moisture on soil at 100°C.

Depth.	*Gliricidia* unlopped.	*Gliricidia* lopped.	Boga unlopped.	Boga lopped.	Control.
0- 3 in.	11·53	13·53	13·65	11·53	9·77
3- 6 in.	15·17	19·84	18·21	18·07	17·35
6-12 in.	17·82	23·31	18·82	23·10	22·51
12-24 in.	25·63	24·15	22·64	26·73	27·52

It will be seen that in the case of the bush green manure plants (1) the moisture contents of the soils from the unlopped plots are less at most depths than those from the lopped and control plots. This is to be expected owing to the fact that the shade effect of these bushes on the soil is not appreciable, while the losses of moisture by transpiration from the crop are great; (2) the forking in of these green manures has had beneficial results, the amounts of moisture contained in the soil samples from the lopped plots being greater than those from the controls. Previous soil moisture determinations generally confirm the above conclusions.

THE COVER PLOTS.

Soil moisture determinations of samples from these plots were made on the 27th February 1928 and again on the 24th January and 24th February 1929. The covers were cut and envelope-forked into the soil in the lopped plots on the 28th November 1927 and again on the 13th October 1928. There was therefore a sufficient interval between the turning in of the covers and the soil sampling to permit of the re-growth of the covers. The results are shown in tables V and VI below.

Table V.

Per cent. moisture on soil at 100°C.

Depth.	*Indigofera* uncut.	*Indigofera* cut.	Vigna uncut.	Vigna cut.	Control.
0- 3 in.	12·76	11·61	12·15	11·85	9·16
3- 6 in.	14·15	14·87	13·58	16·02	11·00
6-12 in.	17·93	17·13	15·90	18·56	23·26
12-24 in.	20·78	20·12	19·21	24·42	24·96

Table VI.

Per cent. moisture on soil at 100°C.

Date of sampling. 22-1-29.

Depth.	*Indigofera* uncut.	*Indigofera* cut.	Vigna uncut.	Vigna cut.	Control.
0- 3 in.	12·85	9·00	14·14	9·50	9·07
3- 6 in.	16·96	14·59	14·46	16·69	14·07
6-12 in.	19·19	19·98	18·60	19·34	19·22
12-24 in.	21·32	23·28	19·33	21·74	21·92
		Date of sampling. 23-2-29.			
0- 3 in.	11·88	9·34	12·49	12·91	8·99
3- 6 in.	13·46	13·01	14·04	14·64	12·20
6-12 in.	17·27	17·08	16·98	16·01	14·38
12-24 in.	21·83	20·74	18·82	16·74	19·33

It will be seen that though there are greater amounts of moisture present in the upper 3 inches of soil in the uncut than in the cut plots, the amounts of moisture in soil samples from the lower depths are greater in the cut plots, especially in the early stages of the drought. As the drought advances the uncut plots appear to retain more moisture at most depths than the cut plots. This is probably because the transpiration from the renewed growth of covers on the cut plots and the lack of a surface mulch of decayed organic matter more than counterbalance any beneficial effects on soil moisture of the comparatively small amounts of organic matter turned into the soil; (2) both cut and uncut cover plots have more moisture than the control at nearly all depths. This confirms what has been previously found.

GENERAL DISCUSSION AND SUMMARY.

The results of moisture determinations on soil samples taken at various depths up to 24 inches from tree, bush green manure and cover plots at the Experiment Station, Peradeniya, during 1928 and 1929, confirm generally the results of previous work on the relation of cover crops to soil moisture at Peradeniya. In addition, the following conclusions appear to be indicated:

In the case of the tree green manure plots the shade afforded by the trees, where good, appears to be an important factor in counterbalancing losses of soil moisture by transpiration from the leaves and from the soil surface by evaporation provided the drought is not too prolonged. The correct time of burying green manures is another factor of importance. Green manure loppings should not be turned into the soil prior to or during dry weather or great soil moisture losses will result. The most suitable time for lopping the trees and forking in the loppings appears to be towards the end of the rains when dry weather is likely to alternate with wet. This will result in speedy decomposition of the loppings in the soil and will increase the moisture-retaining capacity of the latter. In dry districts it is preferable to lop the green manure trees before the drought sets in and to leave the loppings as a mulch on the surface.

Bush green manures should be treated similarly to the tree green manures, but they should not be allowed to continue to grow during periods of drought, as the shade they afford does not appear to counteract losses of soil moisture through transpiration.

Soils planted to cover crops either periodically cut or left uncut are found to retain more moisture than bare soils at nearly all depths up to 24 inches. The results of previous work on the subject are therefore confirmed.

ACKNOWLEDGMENT.

The authors acknowledge their thanks to the Manager, Experiment Station, Peradeniya, for his assistance in the taking of some of the soil samples and for having made this investigation possible.

THE RELATION OF GREEN MA NURES TO THE CARBON AND NITROGEN CONTENTS AND REACTION OF SOILS AT PERADENIYA.

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IT is well-known that most cultivated soils in Ceylon generally lack organic matter and that no accumulation of the latter ordinarily takes place in these soils if they are well drained and aerated. This is, as Mohr (1) found in Java, because the moisture and "temperature conditions over the greater part of the island are more favourable for the organic matter decomposing micro-organisms of the soil than for the higher plants which furnish the materials for these organisms to act upon, the organic matter being destroyed as rapidly as it is supplied by plants." Where the average temperature is below 25°C, as in certain districts up-country, the conditions are more favourable for the accumulation of organic matter than for its decomposition.

In temperate regions where green manuring has been practised large gains in soil organic matter and nitrogen have been recorded. Green manuring has been done on tea estates in Ceylon for many years, and, while published data are not available to indicate how the organic matter and the nitrogen contents of the green-manured soils have been affected thereby, there is little doubt that there has been an appreciable increase of these constituents in many of the soils so treated. Eden (2) has shown that soil from an estate which had liberal green manuring had a higher organic matter content than one which was not so liberally green manured. The results of nitrogen and loss on ignition determinations on soil samples from the tea plots under *Indigofera endecaphylla* at the Experiment Station, Peradeniya taken after a two years' growth of the cover showed, on the whole, a slight gain in nitrogen and an appreciable increase in the percentage loss on ignition (3). The latter may be considered to give an approximate value for the organic matter content of the soils. Nitrogen and organic matter determinations on samples taken in November 1929 after a further period of two years' growth show that there are, on the average, further marked increases in the nitrogen and organic matter contents of these soils. With a view, however, to securing definite data as to

the effects of green manures, differently treated, on the carbon and nitrogen contents of soils at Peradeniya, determinations were made of these constituents on soil samples taken during 1928 and 1929 from the permanent green manure plots at the Experiment Station, Peradeniya. The hydrogen ion values of these soils were also determined in order to ascertain the effects of green manures on soil reaction. These determinations will be carried out regularly in the future.

The plots at the Experiment Station comprise the following:

A. *Tree plots.*—(1) *Gliricidia* unlopped, (2) *Gliricidia* periodically lopped and loppings envelope-forked into the soil, (3) dadap unlopped, (4) dadap lopped as in (2), (5) control.

B. *Bush plots.*—(1) *Tephrosia candida* (boga) unlopped, (2) *Tephrosia candida* lopped as in A (2), (3) *Crotalaria anagyroides* unlopped, (4) *Crotalaria anagyroides* as in A (2), (5) control.

C. *Cover plots.*—(1) *Dolichos hosei* (Vigna) uncut, (2) *Dolichos hosei* cut as in A (2), (3) *Indigofera endecaphylla* uncut, (4) *Indigofera endecaphylla* cut as in A (2), (5) control.

The green manures and cover plants were planted out in late 1926 and early 1927. The control plots were clean weeded. No record of the weights of green material were kept. The green manures in the lopped plots were periodically lopped or cut and forked into the soil. The *Crotalaria* plots were replanted in 1928. Soil samples were taken as follows: three soil borings were taken from each plot, these were mixed together and a sample of the mixed soil retained for analysis. These soils were sampled in March 1928 and 1929.

METHODS OF ANALYSIS.

All analytical determinations were made on soil sieved through a 3 mm. sieve and ground down to pass a 1 mm. sieve. *Carbon* was determined by the wet combustion method adopted by Watts (4) and recently recommended by Hardy (5). The results obtained by this method are lower than those obtained by the dry combustion method. Comparative determinations of the carbon contents of four of these soils by the two methods show that the wet combustion method gives, on an average, 10 per cent. lower results than those obtained by the dry combustion method. The carbon results obtained by the former method should therefore be multiplied by 1·1. *Nitrogen* was determined by the Kjeldahl method and *hydrogen ion* (P_H) values by the Biilman quinhydrone electrode.

RESULTS AND DISCUSSION.

The results of the carbon and nitrogen determinations are shown in tables I and II below.

Table I.

Plot.	Per cent. carbon. 1928.	Per cent. carbon. 1929.	Increase or decrease.	Per cent. nitrogen. 1928.	Per cent. nitrogen. 1929.	Increase or decrease.	Carbon/nitrogen ratio. 1928.	Carbon/nitrogen ratio. 1929.	Corrected carbon/nitrogen ratio. 1928.	Corrected carbon/nitrogen ratio. 1929.
Dadap unlopped.	·893	·900	+·007	·102	·093	—·009	8·8	9·7	9·7	10·7
Dadap lopped.	·933	·862	—·071	·106	·096	—·010	8·8	9·0	9·7	9·9
Gliricidia unlopped.	·940	·922	—·018	·104	·102	—·002	9·0	9·0	9·9	9·9
Gliricidia lopped.	1·004	·919	—·085	·109	·105	—·004	9·2	8·8	10·1	9·7
Tree control.	·892	·830	—·062	·097	·086	—·011	9·2	9·5	10·1	10·5
Boga unlopped.	·840	·859	+·019	·097	·099	+·002	8·7	8·7	9·6	9·6
Boga lopped.	·906	·906	+·000	·103	·105	+·002	8·8	8·7	9·7	9·6
Crotalaria unlopped.	·827	·757	—·070	·100	·090	—·010	8·3	8·4	9·1	9·2
Crotalaria lopped.	·857	·860	+·003	·096	·096	+·000	8·9	9·0	9·8	9·9
Bush control.	·830	·695	—·135	·097	·080	—·017	8·4	8·7	9·2	9·6
Dolichos (Vigna) unlopped.	·982	·944	—·038	·123	·110	—·013	8·0	8·6	8·8	9·5
Dolichos (Vigna) lopped.	·939	·959	+·020	·115	·108	—·007	8·2	8·9	9·0	9·8
Creeper control.	·816	·782	—·034	·100	·087	—·013	8·2	9·0	9·0	9·9
Average.							8·7	8·9	9·6	9·8

Table II.

Plots.	Per cent. carbon. 1928.	1929.	Per cent. nitrogen. 1928.	1929.
Tree unlopped plots (average).	·916	·911	·103	·097
,, lopped ,, ,,	·968	·890	·107	·100
,, control plot ,,	·892	·830	·097	·086
Bush unlopped plots ,,	·833	·808	·098	·094
,, lopped ,, ,,	·881	·883	·099	·100
,, control plot ,,	·830	·695	·097	·080
Creeper unlopped plots ,,	·982	·944	·123	·110
,, lopped ,, ,,	·939	·959	·115	·108
,, control plot ,,	·816	·782	·100	·087
Average of all unlopped plots.	·910	·888	·108	·100
,, ,, ,, lopped ,,	·939	·910	·107	·104
,, ,, ,, control ,,	·846	·769	·098	·084
Average of all green manured plots.	·924	·899	·107	·102
,, ,, ,, control plots.	·846	·769	·098	·084

An examination of tables I and II will show that (1) on the whole there appears to be a slight decrease in the carbon and nitrogen contents of the green manured plots although certain individual plots show increases. The decrease, however, is so small that it may be stated that by the use of green manures the carbon and nitrogen contents of a soil are maintained under Peradeniya conditions; (2) the control plots lose appreciable amounts of carbon and nitrogen, even though they are uncultivated; (3) the average carbon content of the lopped plots is slightly higher than that of the unlopped plots, but both sets of plots show slight losses during 1928-1929. The tree lopped plots, however, show distinct losses of carbon and nitrogen due probably to the loppings having been rather woody. The *Crotalaria* unlopped plot shows appreciable losses of carbon and nitrogen, due probably to the replanting of this plot entailing cultivation losses and to the non-addition of any organic matter; (4) the carbon/nitrogen ratios of these soils calculated on the data obtained are, on the average, 8·7 and 8·9 for 1928 and 1929 respectively. When the correction factor is introduced, these become respectively 9·6 and 9·8. It will be seen that the carbon/nitrogen ratios of these soils, as in the case of soils of temperate regions, remain about 10.

In table III below are shown the results of the hydrogen ion determinations on the soil samples.

Table III.

P_H values.

		Dadap unlopped.	Dadap lopped.	Gliricidia unlopped.	Gliricidia lopped.	Tree control.	Boga unlopped.	Boga lopped.	Crotalaria unlopped.	Crotalaria lopped.	Bush control.	Dolichos (Vigna) unlopped	Dolichos (Vigna) lopped.	Indigofera unlopped.	Indigofera lopped.	Creeper control.
1928	P_H values.	5·34	5·79	5·86	5·73	5·73	5·73	5·89	6·03	5·76	5·69	5·96	6·40	5·73	6·20	6·28
1929		5·85	6·06	6·16	6·10	5·98	6·44	5·79	6·10	6·21	5·99	6·57	6·53	6·32	6·32	6·40

It will be noted that there has been an increase in the P_H values of the soils during 1928-1929 indicating that the plots which were initially distinctly on the acid side are becoming less acid as a result of the treatments. This is probably due to (1) the prevention by the green manure crops of the leaching of the soluble bases to lower soil depths; (2) the addition to the upper layers of soil of the soluble bases contained in the green manure loppings and cuttings. In the case of the control the comparatively smaller increases may probably be caused by the lateral flow of water containing soil bases from the adjoining plots.

SUMMARY.

The results of carbon and nitrogen determinations carried out on soil samples taken from the permanent green manure plots on the Experiment Station, Peradeniya, appear to indicate that under the conditions of these experiments there are only very slight losses of carbon and nitrogen from the plots on which green manures are grown or ploughed in as compared with appreciable losses of these constituents from the control plots even though the latter are uncultivated. The losses from the green manure plots are so small that it may be stated that the carbon and nitrogen contents are being maintained by the use of green manures. The carbon/nitrogen ratios of the soil examined are about 10, which is also the average for soils of temperate climates. The results of hydrogen ion determinations indicate that the soils of all the plots appear to have become much less acid as a result of the growth of green manures.

ACKNOWLEDGMENT.

The authors acknowledge their indebtedness to the Manager of the Experiment Station, Peradeniya for having made possible the carrying out of these determinations.

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Epidendrum Stamfordianum Bateman.

EPIDENDRUM STAMFORDIANUM BATEMAN.

K. J. ALEX SYLVA, F.R.H.S.,
ASSISTANT CURATOR,
HENERATGODA BOTANIC GARDENS.

THIS beautiful epiphyte is a member of a large genus of South American orchids which numbers over four hundred species. Most of them are epiphytic on trees, whence the generic name, though not a few are terrestrial. Of this genus of orchids, only a few are considered to be of horticultural merit; the rest consist mostly of species with inconspicuous and unattractive flowers.

Epidendrum Stamfordianum is a robust-growing species with long pseudo-bulbs, tapering below and sheathed with large white membranous scales. The leaves are thick and fleshy and three to four sprout from the apex of the pseudo-bulb and are about 5 to 6 inches long and $1\frac{1}{2}$ to 2 inches broad, thicker near the base and tapering above and below. The flower peduncle arises from the base of the stalk of the pseudo-bulb and bears a compound panicle of racemes of numerous fragrant greenish-yellow flowers with pink spots.

Culture.—The plant does not tolerate much root disturbance and it should be allowed to remain in the same receptacle undisturbed for at least two or three years before repotting which should be done only if the compost becomes impoverished or the plant outgrows the pot. This species ordinarily requires cultural treatment similar to that afforded to Cattleyas and Laelias. In potting the plant should be carefully examined for decayed pseudo-bulbs or roots which should be removed together with old compost. Propagation is effected by the division of the plant with two or three pseudo-bulbs, a growing lead being allowed to each division. The plant should be arranged in the centre of a pot or wooden basket and a compost made up of equal parts of charcoal, decayed wood, bones, coconut fibre and fern roots (*Asplenium nidus*) should be gradually inserted into the pot and pressed firmly to keep the plant in position. If necessary a couple of stakes may be driven into the contents of the pot to maintain the equilibrium of the plant till it takes root.

Watering should be done sparingly and at long intervals so that the surface soil may become dry during the intervals until the plant is well established. As soon as the plant puts forth new growth or fresh leaves, an increased supply of water will be required till the plant attains a normal growing state. It will thrive best in a warm place exposed only to the morning sun.

A good healthy plant will carry flowers for several weeks under moderately dry conditions. Small or weak plants should not be allowed to carry flowers over a long period as the flowering is a drain on the plants and they will take a long time to recuperate and come back to their normal state of growth.

The best time to cut and remove a flower spike from a weak plant is at the stage of opening of the flowers. At this time of its growth root action is encouraged and the plant is helped to attain its full development. If the flower spike is removed at an early stage, there is the danger of the plant becoming stunted and giving only abnormal and twisted growth.

CONFERENCE OF EMPIRE METEOROLOGISTS, 1929.

AGRICULTURAL SECTION.

AGRICULTURAL METEOROLOGY: A BRIEF HISTORICAL REVIEW.

OPENING ADDRESS BY SIR NAPIER SHAW, F.R.S., CHAIRMAN.

IT is with great pleasure and no less surprise that I find myself responsible for inviting an assembly of representatives from many parts of the Empire to consider ways and means of bringing our knowledge of weather to bear upon agricultural practice.

Weather has, of course, been a subject of fundamental importance for agriculturists from the beginning of time. It is, I suppose, of equal importance for all the beasts of the field, for the fowls of the air, the insects that infest it, the fish of the river, the lake and the shallow sea. The lower animals must have shared man's interest in the weather and in fact, if we are to believe famous Greek and Roman authors who wrote about the weather, lower animals are so skilled in knowledge of the subject that they notify coming changes which the lords of creation themselves are too slow-witted to divine; and many people are still of opinion that the very hips-and-haws can foretell seasons. But it is undeniable that the first knowledgeable application of meteorology was the planting of grain in a suitable place at a suitable time of year. That was the basis of the first co-operative movement, the dawn of our civilisation. So interwoven is the famer's life with the knowledge of weather that one of the great difficulties in developing the application of meteorology to agriculture has been that, knowing as everyone does that the growth of plants and animals depends on sun and warmth and rain, we could not persuade the farmers to tell us how much sun, how much warmth, how much rain was necessary for a bumper crop. I have said it before, and will say it again, that agricultural meteorology is what the farmer knows and won't say.

But the farmer must have lived there for some time, and his father before him, before he finds a working knowledge of weather bred in his bones. At Washington once, on a visit to the Secretary for Agriculture of the United States (who was in fact a Scotchman, which means a good deal in agriculture), I was much impressed by his telling me why it was necessary for the Ministry of Agriculture to have its Weather Bureau. At that

time a great deal of the United States was virgin soil and the people who were to till it came from all parts of Europe and had not even that rudimentary knowledge of the relation of crops to sites and seasons that I have called the dawn of civilisation. The lesson that James Wilson gave me in Washington comes back to me with more than its original force as I stand in front of an assembly that has to think about the cultivation of crops in the British Empire. If the range of climate and weather in the United States of America requires a Weather Bureau to prevent its citizens' efforts from being wasted, for want of knowledge of the weather and its meaning in beneficence and maleficence, what sort of Weather Bureau does the British Empire require in order to make the most of the soil that it possesses ?

Our own Meteorological Office was started in 1854 for the sea and navigation, not for the land and agriculture. I should not be a bit surprised if the Government of 1854 were of opinion that if anybody wanted to know anything about the weather and climate of the United Kingdom it would be better to ask a farmer than a Fellow of the Royal Society. We are now, of course, in a new world; but probably there have been Ministers since 1854 who have had the same opinion.

Anyway, in 1877, after ten years of inquiry by a Committee of the Royal Society into the relation between meteorological records and weather, a new Council entrusted by the Royal Society with the control of the Weather Office began at once to take up the question of the application of meteorology to agriculture and public health. It was a very strong body of scientific men to whom the control of meteorological work was entrusted. The people who were then thinking about the relation of weather and crops were: Henry Smith, a versatile professor of mathematics at Oxford, who died too soon; Warren De la Rue, a pioneer in the study of the sun; Francis Galton, George Gabriel Stokes and Richard Strachey, with Captain Evans, *ex-officio*, as hydrographer of the Navy, all famous men. For help with their agricultural scheme they consulted two other persons, whose names will be well known in this assembly, J. B. Lawes and J. H. Gilbert of Rothamsted. We look to the same quarter for advice to-day. In order best to serve their common purpose the Council arranged to collect information about warmth and rain and sunshine from representative stations in twelve disricts of the British Isles and to publish it weekly every Wednesday, so that the public authorities might have their information about climate and weather almost as hot as their morning bacon. The first number was issued at the beginning of February, 1878—and the last at the end of January, 1928.

That was the expression of their ideas about practical climatology. Their effort in synoptic meteorology was to issue special forecasts of weather in the harvest season. The publication of forecasts, after some years of intermission for the purpose

of study, had been resumed on April 1, 1879. The following paragraph appears in their Report for the year ended March 31, 1880:—

> "*Hay Harvest Forecasts.*—In order to put the forecasting system to a practical test, the Council, in the month of June, 1879, made proposals to the Royal Agricultural Society, the Royal Dublin Society, and the Highland Society, to send daily forecasts *gratis* during the hay season to a number of observers selected by the Councils of those Societies, on the two conditions, that the information should be made as widely known as possible, and that a record should be kept of the value of each prediction."

Then follows a list of the recipients of the forecasts to the number of 32.

The same paragraph is repeated in practically the same words in the Report of each year until 1899. In 1900 the following paragraphs appeared:—

> "*Harvest Forecasts.*—The practice of distributing, by telegraph, special Forecasts to a selected number of prominent Agriculturists in the several districts of England, Scotland, and Ireland during the period of harvest, had been continued for a long period, in order to give the Council an opportunity of putting the Forecasts to a practical test. The returns of success and failure were made up from the observations of the recipients themselves, and for many years past the totals of partial and complete success had reached an average of about 90 per cent. for all districts, varying from 76 per cent. for Ireland N., to 96 per cent. for England, S."
>
> "In May, 1899, the Council decided that the free distribution of the Forecasts should be discontinued, and a circular was issued announcing this decision, and stating that the Forecasts would be sent to applicants who were willing to pay the cost of the daily telegram, without any additional charge. Twenty applications for the Forecasts were received, one from Scotland, W., and the remainder from the various districts of England, and Forecasts were sent daily at 3-30 p.m. for varying periods extending in the whole over eight weeks."

In 1901 the number of subscribers increased to 129.

In these days when the conclusions drawn from a map prepared from observations made in almost any part of the northern hemisphere at 6 o'clock can be issued by "wireless" at 9 o'clock to a million listeners, we ought to recall the difficulties of distribution with which the meteorologists of the past century had to contend. The main map of the day was based on observations at 8 a.m., a more restricted service of telegrams reported observations at 1 p.m. and 6 p.m. Forecasts were prepared for issue at 11 a.m., 4 p.m. and 8 p.m: the first for exhibition on the office door at 63, Victoria Street, at three places in the City, six places in the West End, and for the London evening papers; the second for exhibition as before and for London and Provincial papers and 125 other subscribers. The 8 p.m. forecasts were originally prepared for *The Times* and then for other subscribing newspapers until it was arranged with Government that they should be supplied at the public expense for the papers of the following morning.

Looking back I think we may say that really an antecedent condition for a successful system of forecasting for agricultural purposes is an effective scheme of distribution by wire or wireless. For farmers, reports by post or newspaper can only be reminiscent. The Council were as fully aware of this as you or I; but the Post Office of those days was a Government Office and the Council's office was not. For the Postmaster-General it was merely a regualr customer. Its telegraphic information had to be paid for in full and had to take its turn with the messages of the general public. An official of the Post Office once informed me, with all the appearance of pride, that the priority in the Post Office was by turn and nothing else. He explained that a telegram from the Police to arrest a murderer would have to wait its turn while a telegram to put half-a-crown on a horse race was being sent. It required the Great War to secure priority for weather telegrams, and then it was indeed such priority as we had never dreamed of.

When a Committee of the Privy Council on Agriculture was appointed the Office appealed for a better trial of the forecasts than it was able to afford itself and in 1893 and again in 1894 trials for selected districts were made. The recipients kept notes of the weather. The harvest forecasts and the weather notes were treated as the material on which to form a judgment about the utility of forecasts and submitted for examination—to a farmer ? No !—to a local resident squire or parson who knew something about crops and the difficulty of getting them ? No !—to a lecturer on Geography in one of the University Colleges. What could anyone in that position say except that no forecast is likely to fit in with the geography of a whole district in England, Scotland or Ireland ? It was a foregone conclusion. The report explained what every forecaster knew better than anyone else, and so the experiment was judged to have failed. May I draw this lesson—that if any of you gentlemen are arranging to issue forecasts for the use of agriculturists in your country and you want to know whether they are useful, don't ask an independent meteorologist to report on your scheme, ask your farmers about their crops and how they got them. Keep your difficulties to yourselves and get over them as quickly as you can: judge your service by its usefulness to those whose work is with crops.

Such is in brief the history of our efforts in the direction of Agricultural Meteorology from 1879 to 1899. During the next twenty years I had some personal share in the responsibility for its development.

As official documents passed through my hands I was impressed with the advantages of the Weekly Weather Report for the purpose for which it was planned and the care that was taken to provide appendices that might stimulate research into the agricultural influence of weekly weather. But in this country, where the study of weather is hardly recognised in higher education, the

stimulus has met with little response. One of the novelties of the report was that at Gilbert's request it estimated warmth as accumulated temperature above or below 42°F., and I was curious to know how that scheme worked; so I put together the results for the twenty years and, knowing hardly anything of crops myself, I was astonished to find that productive barley years were the colder years, not the warmer ones, and that the climate of Eastern England was, in fact, too warm for barley.

Here let me interpolate the story. An ingenious member of my staff demurred to the conclusion. He thought that the method of dealing with such questions by averages of warmth and crops for districts was inadequate. For him the only safe way of arriving at a conclusion was the experimental way—watch your plant all the time and measure the warmth which it received. So he sowed some barley in a pot in his own greenhouse where the conditions of temperature and water supply were under his own observation. When I inquired later how the experimental plan was getting on it turned out that most unfortunately and quite unaccountably the plants had died. But after all it was a very illuminating experiment. I remain still unconvinced that the method of districts and crop returns is not the best way of dealing with mortal things like plants.

Pursuing the matter further I found that the wheat yields for the whole of England, in the years for which the Board of Agriculture provided data, displayed a curious inverse relationship with the rainfall of the previous autumn. You may hear something about it later on. I remember showing the figures to Sir Francis Galton, who had by that time retired from the Council. The gratification that he expressed at something of practical interest having come out of the work in which he had taken a leading part is one of the most pleasurable reminiscences of my life.

By that time a good friend who was a member of the Council of the Statistical Society insisted upon my joining that body, and then, on writing a paper, and as I had satisfied myself that the Weekly Weather Report presented the best thought-out body of meteorological statistics in the world, I naturally used the opportunity to expound its advantages and worked out the relation of wheat crop to autumn rainfall for the Eastern district of England. That still remains for me a subject of natural curiosity and two years ago I was astonished to find a reproduction of the diagram which I had drawn used in a German school of geophysics as the introductory illustration of a general principle.

Thereafter Mr. R. H. Hooker took up the question of the relation of weather and crops on proper statistical methods and with Mr. Yule's assistance developed the method of partial correlation coefficients. The method has spread all over a large part of the world, particularly in India, Sweden and the United States. In the meantime a good deal of useful work on experimental lines

was done in Russia, so that before the War the International Meteorological Committee appointed a committee to study meteorology in relation to agriculture. It is now under the able chairmanship of Dr. Wallén, of the Swedish Meteorological and Hydrographical Service.

The next stage, so far as I am concerned, was in July, 1912, when I was bidden to give a lecture before a Conference of Agricultural Teachers at Cambridge on Meteorology and Agriculture. I doubt if at that time one could have found a more difficult subject for a lecture. It opened with the remark:—

> "There is a wide-spread opinion, more often hinted at than expressed, that meteorology is of great importance in agriculture; yet when one looks around for monumental evidence of its achievement in this country, except for some successes in forecasting, there is little to be seen."

No one doubts that weather is still of the utmost importance in agriculture, as it was in the beginning; but meteorology is not weather, it is the study of weather— a different thing.

Since that time the position has been changed. So far as I knew, any good seed that I tried to scatter on that occasion had fallen by the wayside. Shortly after, the War intervened; yet when the War was over the same desire for co-ordinating the knowledge of meteorology with that of agriculture found expression in the establishment of the Crop Weather Scheme by the co-operation of the Air Ministry with the Ministry of Agriculture. You will hear what has been done and is being done in that way in this and in other countries. Month by month we can see the subject expanding and our purpose to-day is to exchange the experience of methods and results obtained in this country with those of other parts of the Empire.

It has developed far beyond the powers of an ordinary mortal like myself to follow its details.

I am still impressed with the flexibility and power of a weekly report. But in that matter the rationalization of our industry is hampered by the irrationality of what I will call the monthly habit of meteorologists. In this connexion I think we ought all to bear in mind the proposals for the reform of the Calendar which are designed to rationalise the measurement of time, not so much for scientific as for commercial purposes. They have been put forward by the U.S.A. and have been taken up by the League of Nations with the suggestion of an "International Conference to decide Calendar Reform."

The following notification comes to me with a post mark S.W.1:—

> "International Chamber of Commerce, Amsterdam Congress.
>
> "The International Chamber of Commerce, earnestly desiring that the date of Easter should be fixed without delay, and that the calendar should be reformed, reaffirms at its 5th Congress in Amsterdam its previous resolutions of the 1st Congress at London, 1921, the 2nd Congress at Rome, 1923, and the 3rd Congress at Brussels, 1925.

"The Chamber notes with satisfaction that several nations at the instance of the League of Nations have organized Special Committees to study calendar improvement and the fixing of Easter.

"The Chamber urges that other nations should follow that same practical course, and that the League should convene an international conference to secure without further delay the improvement for which the world's commerce has so often asked."

I do not gather that the reform of the calendar excites much interest in this country. Indeed, when I broached the question in a paper before the Royal Statistical Society in 1925, "On the week or month as an intermediate time-unit for statistical purposes," the Government officials who took part in the discussion seemed to think that the present lack of system, in spite of all its imperfections, was better than anything else. Still the International Chamber of Commerce may have an influence with Boards of Trade and Ministries of Air and Health that simple reasoning does not command. All I would say now is that we are not much concerned about a fixed or movable Easter, that for meteorology or agriculture there is no such thing as a *dies non*, and I doubt very much if there can be one for commerce—certainly a Bank Holiday is not one. If there is a day to spare from the calendar it might be spent in universal work for some laudable object of universal interest, say the League of Nations, or, better, the organisation of a universal campaign against the minor enemies of mankind.

But the choice of a time-unit is really a subject of vital importance for the proper organisation of the endeavour to co-ordinate agricultural progress with the study of weather. In my capacity as President of the Meteorological Section of the International Union for Geodesy and Geophysics, in accordance with a resolution passed at Prague in 1927 I have to organise a deputation to the International Meteorological Committee this year. I am afraid that illness has stunted my personal activity, but if you agree with me that choice of a time-unit is a really important matter, you may make some amends for my enforced inactivity.

Let me, in conclusion, say a word or two that I hope may be regarded as in season in opening a conference upon what is practically a new science, and that is the urgent necessity in all sciences for scrupulous care in the choice of words to express new ideas. It is so easy when one is thinking out a subject to borrow for a new idea a word that is already in common use and give it another meaning; if a distinction is to be drawn we are apt to accomplish our desire by adding an adjective.

I wonder how much lead meteorology has lost by using the name absolute temperature for something which for the man-in-the-street is not temperature at all. Our friend in the street is entitled to say to the man of science: "You have encouraged me to buy an instrument to measure temperature; and for me temperature means what I read on that instrument and can mean

nothing else." It is not only the man-in-the-street who is misled. Some years ago two Oxford physicists, Lindemann and Dobson described some observations from which they concluded that the "temperature" of the air at a height of 100 km. is about 300, and only a few days ago in a paper from Copenhagen I find a discussion based upon the figure 300°C. as the temperature referred to: but 300°C. is 273°C. wrong.

I quote the incident to suggest that as the scientific world has invited the man-in-the-street to read temperatures on a thermometer, it should leave him in possession of the name and find another name for what we scientific folk call absolute temperature. We might have made some progress if we had used a new word, "thermancy" for example and if Lindemann and Dobson had said that the thermancy of the air at 100 km. was 300 the Copenhagen printer would have done no harm.

You may think this is very remote from agriculture, but radiation, the foundation of all agriculture, is reckoned in absolute temperature, not in temperature. When you lose a potato-crop in a night-frost in May, if you are a meteorologist you may perhaps find a grain of scientific consolation in reflecting that it is thermancy that counts, not temperature.

Really one ought not to alter the essential nature of an entity by qualifying it with an adjective, though the attempt is often made. A year or two ago, in a review of a work on the glacial anticyclone, I had occasion to contrast some of its properties with the recognised properties of an anticyclone. The author demurred and explained that anticyclone was not in his book nor in his index; it was a "glacial anticyclone" not an "anticyclone" that he was talking about.

Such things happen often. When I was at the Meteorological Office we used to keep a catalogue of all gales on the British coasts. The gales we catalogued were defined as winds of force 8 on the Beaufort scale. The meaning of our catalogue was obscured by the fact that force 7 on the Beaufort scale was called a moderate gale, so we altered moderate gale to high wind; but I see the old notation has become re-established, and if you want an answer to the conundrum: "When is a gale not a gale ?" you must ask a seaman, and he will explain: "When it's a moderate gale."

Let me give one other example of the need for care in the choice of words. Things happen sometimes in nature that are outside the pale of properly organised statistics. You may get a succession of events which to the unsophisticated person looks periodic: you may even guess the period. But the statistician has his own canons of behaviour for periodic things, and when things look periodic and do not satisfy his canon he is apt to say they are "accidental." But for the observant meteorologist, as I suppose for the observant agriculturist, there are problems in

nature but certainly no accidents. Accident is, I am sure, quite the wrong word to use. I should understand at once if he called the sequence "ultrastatistical," meaning that a statistician would not think about it. I should forgive his calling it "infrastatistical" as being beneath the notice of a person who dealt with ordered arrangements of events. But if he calls it accidental I spend all my little leisure for his subject in wondering why he uses such an inappropriate word.

Pray excuse my calling your attention to these small matters. You have a very extensive bill of fare before you, and compared with the subjects in the programme what I have mentioned may be what the French would call "*hors d'œuvre.*" Yet perhaps I may be forgiven if I use another analogy. In science as in transport, switch points have no prominence and yet they have quite considerable importance.

Returning from the minor to the major key—what after all is this Agricultural Meteorology that we are asked to discuss ? Is it meteorology at all ? or is it one of the things that I have referred to, the very nature of which is changed by its epithet ?

We are, of course, agreed that the human race depends upon its agriculture for its food and clothing; the science of agriculture may fairly be described as the study of the organised reaction between soil and weather, and meteorology is the study of weather. The most obvious feature of this everlasting reaction is that changes in the soil are interminably slow compared with the changes in the weather and the two require different arrangements for their study.

One aspect of Agricultural Meteorology is the presentation of one side of the reaction between soil and weather in any particular agricultural problem; but that is only one aspect. Another is the presentation of our knowledge of weather in such a form that we can follow in outline, if not in detail, the progress of the reaction in any selected locality. It is this second aspect which makes a special appeal to us to-day. If we organise to the best advantage our knowledge of weather—that knowledge which in the past has merely gone to increase what a distinguished American meteorologist has called the "frozen assets" of the science—we shall obtain a general view of the progress and prospects of agriculture in every part of the Empire.

To devise and organise an arrangement which is equally suitable for all and each of His Majesty's Dominions will require courage as well as ingenuity—courage of a peculiar order if the best arrangement is one which has to override the awkwardness of the Georgian calendar. But the object of our work, the understanding of the conditions under which the different parts of our wide-flung Empire contribute to the world-supply of food and clothing, is no mean ambition.

SELECTED ARTICLES.

KAPOK IN THE PHILIPPINES.*

ALTHOUGH kapok has been known commercially for more than a century, it has not until quite recently attained any considerable commercial importance. The admirable qualities of the floss for filling purposes were first made known to the commercial world about the year 1850, when the Dutch in Java began to export it in small quantities, first to Holland and later to Australasia and the United States. Since that time Java has been the principal, in fact practically the only source of supply, although the tree and its product are well known in several other tropical countries.

In the Philippines the trees produce several thousand tons of floss of which a comparatively small part is used locally, and practically the whole of the remainder is left to rot on the ground. It is only since 1905 that an attempt has been made to export the fiber from the Philippines and, even since then, the quantity exported annually is entirely too small in proportion to the amount produced.

The activities of the Bureau of Agriculture, directed towards the establishment in the Philippines of an export trade in kapok, are traced back to the year 1903. Between the years 1903 and 1909, the activities consisted in, first, a study of the kapok trade of Java; second, a general investigation as to the extent of the cultivation of the kapok tree in the Philippines, its average yield, and the local uses made of the floss; third, the preparation and distribution of circulars and other publications intended to correct the faulty methods and practices used by the natives in planting and harvesting; fourth, the free distribution of seeds and seedlings; and, fifth, an attempt to provide better means for cleaning the product.

Several campaigns have been conducted by the Bureau of Agriculture to induce the people to plant kapok trees on a large scale, and many people did set out numbers of trees in Tarlac and Bataan and other places in Luzon; but as they found no market for the product the trees got neglected. For example: a big kapok plantation in Bataan consisting of 2,000 three-year-old trees produced 77,000 pods in 1921, its first crop, but as only pesos 269 was received therefor no further attempt was made to sell the pods except locally.

But since kapok has made a market for itself, emphasis must be laid on the word "good." Philippine kapok is produced by the plant botanically known as *Ceiba pentandra* Gaertn., the same as Java kapok, which is superior because it is handled carefully and prepared for the market in accordance with the strict grading regulations of the exporting firms, as was learned in an investigation conducted by a representative of the Bureau of Agriculture, who visited Java in 1920.

Climate and soil.—The kapok tree requires not more than 2,000 milimeters total annual rainfall. A climate with a pronounced difference between the dry and wet season is preferable, and decayed volcanic soil or a porous soil.

* From *The Philippine Agricultural Review*, Vol. XIX, No. 3, 1926.

Propagation and planting.—Kapok is propagated both by seed and by cuttings, but the former method is recommended, for it gives robust and better plants, while the latter produces plants which are susceptible to the attacks of termites or white ants. The seeds are planted first in seed beds and the seedlings are then transplanted when they attain a height of about a meter.

Harvesting and cleaning the floss.—The pods should be picked as soon as ripe, but never before; nor should they be left to open on the trees, as both practices tend to lower the grade of the product. As soon as picked they should be opened, classified, and cleaned, even before the floss is thoroughly dried. The floss should be dried as soon as possible, however, to prevent fermentation, which might take place, and thus retain the grade and quality.

Cleaning the floss by machinery.—The machines thus far constructed perform their function on very much the same principle, as all or most of them have been based on the more improved hand process of cleaning the floss. These machines are as a rule simple, both in construction and operation, strong, cheap, and portable, thus affording an opportunity for all classes of kapok producers to use them to advantage, provided that sufficient trees are grown in close proximity to render their use practicable.

The general principle upon which the most successful kapok machines are based may be described as follows: A long rectangular or polygonal box, or chamber, is set horizontally or perpendicularly. Through this chamber runs a shaft, on two opposite sides of which are adjusted a number of pins, or blades, either opposite each other or alternating at regular intervals. From two or more sides of the chamber other blades extend, which do not touch the former blades but pass a few centimeters in front of them. Both blades are removable and can be adjusted in their proper places by screws. The former blades stir the floss while revolving with the shaft, and in so doing beat it against the latter fixed blades. The revolving blades are adjusted to the shaft in a manner similar to the blades of the propeller of a steamer, which moves the floss from one end of the chamber where the floss is fed into the other end where it is driven out, In front of the outlet some machines are provided with a fan which blows the cleaned floss through the outlet into a large rectangular removable receptacle in which the individual fibers are deposited like the flakes of snow. The particular advantage of the fan is in freeing the floss from any extraneous matter, such as dust, pieces of broken leaves and twigs, etc., which is often found mixed with the floss. The seed falls through the perforated base of the chamber as a result of the violent stirring effected by the blades of the revolving shaft.

The following are the cleaning machines so far known:—

1. *The Bley machine,* invented by Mr. G. Bley, a prominent kapok planter of Java. This machine is supposed to be one of the best machines so far invented. It requires one-half to 1 horse power for its operation, and is claimed to clean about 217 kilos of floss per hour. This machine was exhibited and operated at the Sourabaya Fiber Congress and Exhibition held in July 1910, and was awarded the first prize.

2. *The Becker machine,* invented by Messrs. Becker & Co., Sourabaya, Java. This machine works on the general principle of the Bley machine, differing from the latter principally in having the cleaning chamber set perpendicularly instead of horizontally as in the Bley machine, and in its operation and construction being perhaps a little more complicated than the latter. It is claimed that this machine cleans about 120 kilos of kapok floss per hour.

3. *The Lienau machine,* invented and manufactured by some English firm whose name is not known. This machine was imported here by Mr. Felix Lienau of Manilla, hence the name given it here. It is built on very much the same general plan as the Bley machine, but is much smaller in size than the latter and is not provided with a fan. It requires from one-half to 1 horse power for its operation, and will clean between 120 and 130 kilos per day of ten hours. Its simplicity of construction, the inexpensiveness of its operation, and its low cost would indicate that it can be operated to advantage on small plantations.

4. *The Kapok cleaning machine of the U. S. Naval Station, Cavite, and the Bureau of Agriculture.*—In 1916 a machine was built by the Department of Construction and Repairs at the United States Naval Station, Cavite, Philippine Islands, which has given very satisfactory results in separating the kapok fiber from the seed. The Fiber Division co-operated with the Naval Station by furnishing plans and data of similar machines used successfully in Java. A machine of the same design is at present in the Singalong Repair Shop of the Bureau of Agriculture.

YIELD.

From several observations made by different persons in different localities, it appears that an estimate of the annual yield of clean kapok from a tree of normal growth and under 7 years of age may be placed at 350 to 400 pods. Trees between 7 and 10 years should yield an average of 600 pods or more.

A very wide divergence is also encountered in the yield of floss by pods. While in some cases about 150 pods will yield 1 kilo of clean kapok, in others it may take as many as 300 to yield the same quantity. In this respect it is probably safe to calculate on 230 pods to produce 1 kilo. The judicious selection of seed for planting will undoubtedly increase the average yield of floss in the pods.

On the above basis a hectare planted to kapok, and containing 280 trees from 5 to 7 years of age, ought to bear 95,000 to 100,000 pods, which at the rate of 230 pods to the kilo, will yield 410 to 480 kilos of clean kapok per year. From the seventh to the tenth year, a hectare should yield about 640 kilos.

In a general way it may be said that the yield of seed is double that of the floss. That is, a tree which generally yields 3 kilos of clean kapok during the year yields also about 6 kilos of seed. Various tests have shown that the weight of clean kapok varies from 55 to 65 per cent. of the weight of the seed. The yield of seed is also variable both as regards the number and the size of the individual seeds.

USES.

The principal use of the greater part of the kapok produced, however, is for filling pillows, cushions, mattresses, and other similar articles of upholstery. Next to this use may be mentioned its use for filling buoyant cushions. Finally, may be cited its most recent use for textile purposes.

For upholstery purposes kapok is preferred to all other filling fibers on account of its great capacity for filling and also its great elasticity. The latter is demonstrated by the fact that all cushions and mattresses that are filled with kapok will, after the pressure is taken away, resume their previous dimensions. In other words, kapok does not get matted with use, as is the case with all the other filling materials. Its great capacity for filling is shown by the fact that the weight of the quantity of kapok required to fill a certain mattress is considerably less than that of any other material used for the same purpose.

The use of kapok in buoyant cushions dates back to a very recent period, prior to which cork was almost exclusively used. Now the former is gradually replacing the latter, and it is only a matter of a few years when kapok will be used to a greater extent than cork for this purpose. This recent use made of kapok has increased the demand therefor and manufacturers of articles of upholstery have already begun to complain of the excessive price of the raw material.

BY-PRODUCTS.

The most valuable product of the kapok tree is, of course, its floss. Next to this in value and importance is the seed, which has also become an article of trade, for it contains 23 per cent. of oil.

The oil is used to a great extent in the manufacture of soap and as an adulterant for other oils; the residue, or cake, is sometimes used as cattle food and as fertiliser. The weight of the seed is, roughly speaking, double that of the floss.

The wood of the kapok tree, which is light and soft, is used for tanning leather and for other minor purposes. The tree yields a dark-red, almost opaque, gum which has some medicinal value. The bark contains a reddish fiber which is sometimes used for tying purposes.

THE ORIGINAL HOME AND MODE OF DISPERSAL OF THE COCONUT.*

THE origin and mode of dispersal of the coconut, which is now widespread throughout the tropics of the Old and New Worlds, has long been a subject of discussion. De Candolle, Beccari, Chiovenda, and others consider the coconut originated in the Indian Archipelago or in the Pacific Islands, while O.F. Cook attempts to prove that its origin was in the valleys of the Andes of Columbia in South America and that it was transported thence, entirely by human agency, far and wide across the tropic seas. H.B. Guppy also holds the opinion that the home of the genus *Cocos* is in America, while Geoffrey Smith states, on information given him by Mr. Hedley of Sydney, that the coconut was introduced to the Pacific Islands from Mexico by Polynesian mariners. Cook asserts that it is highly improbable that sea-borne coconuts could ever be cast up on a shore in such a favourable position that they could germinate without the aid of man, and Schimper considers that the coconut groves "fringing most tropical coasts have only exceptionally originated without human aid." The fact remains, however, that coconuts are the common strand palms on almost every tropical island and that they were found well established when many of these uninhabited islands were discovered.

Another fact which lends support to the original home of the coconut being the Indian Archipelago or Polynesia is the great variety of the coconuts now found in the East. Many of these varieties have well-marked characteristics, such as colour of the nuts, thickness of the husks, etc., and many of these special kinds are grown specially for religious ceremonies among the Hindus, which also points to the palm being of great antiquity in South India. The hereditary occupation of the Tiyans of the Malabar Coast also is the tapping of coconuts for toddy. Then, again, the Tamil and the Malayalam name for the coconut is *tengai* (*ten*=south, *kai*=fruit), that is, the fruit which comes from the south.

Chiovenda quotes a reference to the coconut in Indian medical literature, supposed to date back to 1400 B.C., and a statement of Ctesia that coconut oil was in common use in India in 400 B.C. He cites evidence that the coconut was widely cultivated in the Gangetic Plain in the first century of the Christian era, and refers also to two Arabian travellers, Abu Said and Ibn Wahab, who in the ninth century went as an envoy to China and reported that the Laccadive and Maldive Islands were covered with coconut palms, which appeared to be indigenous there. One of these travellers also made the interesting statement of the existence in India of a religious sect, which, for humanitarian reasons, introduced and propagated the coconut on those islands where it did not already exist.

The name 'coco' appears to be due to the Portuguese, and they were made acquainted with the palm from their voyages in the East. The commonest word in the languages of the Pacific for the coconut is some form of the Indonesian *niur* (*niu, nu*), and everything points to these names being of great antiquity, thus lending additional support to the coconut belonging to this part of the world. Mr. S. H. Ray, in a letter to me on the matter, suggests that the fact of the coconut having other names among the Papuan and Melanesian peoples and traces of others in Indonesia seems to point to it being indigenous in the Islands.

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* By Dr. Arthur W. Hill, C.M.G., F.R.S., in *Nature* of July 27, 1929.

In connexion with the Polynesian Islands being the original home of the coconut palm, Beccari lays stress on the occurrence of the robber crab, *Birgus latro,* in these Islands. This remarkable crab is able to break open the coconut shells with its heavy chelae by hammering with them on the 'eye hole' until a large enough opening is made for it to insert its small chela in order to extract the pulp or endosperm. It also ascends the palms for the purpose of getting the nuts, and is said to put its abdomen into the shell and carry it about with it as a protection. Another interesting point suggesting that the association of the robber crab and the coconut must be of great antiquity is afforded by the fact that the crab uses the husk of the nut for lining its borrows. Beccari considers this association of the crab with the coconut affords further support to the view that the coconut originated in the Polynesian region. Geoffrey Smith, however, does not believe the association of the *Birgus* with the coconut is of very ancient origin, possibly because he accepted the information given him by Mr. Hedley, that the coconut was introduced to the Pacific Islands from Mexico by Polynesian mariners.

Although there is this remarkable association between the crab and the coconut, it is only right to point out that the crab is found on islands where there are no coconuts and *vice versa,* also that the crabs are commonly found on the fruit clusters of *Pandanus,* the screw pine, the individual segments of which are much chewed and squeezed by the crab.

F. W. Christian gives the names *kuku* from Rarotonga and the Gilbert Islands and *kukuma* in the Marquesas for the robber crab, and also quotes the Arabic *khukhum* (a crab), and the Mäori *kuku* (to nip). These names suggest a possible connection with the Portuguese *coco.* Dr. C. O. Blagden, however, who has kindly looked into the matter, has sent me the following letter, which shows that there are no grounds for connecting the name 'coco' with any native names of the crab :—

"On the face of it, it seems to me somewhat unlikely that the name of the cocopalm should have been derived from that of the land crab (or other crab), that preys upon it. Man is much more interested in the many uses he derives from the tree than in the crab; and the tree has, I imagine, a very much wider area of distribution than the crab.

As a matter of fact, however, the name of the tree does not, as a rule, resemble that of the crab. Its most diffused general name in the eastern islands from Madagascar to the Marquesas, is *niur.* Other names, such as *kelapa, kelambir,* and the Celebesian *kaluku* (of which *koekoe, i.e., kuku,* may be either primitive or the reduced form), are more local. So, I should suppose, are such crab names as *kuku* and *kukuma.* In Malay and other Indonesian languages, such as Javanese, etc., there are two words :—

(1) *kuku,* claw, hoof nail (of finger or toe).

(2) *kukur,* claw, to claw, to rasp, probably variants of one word. (There is also a variant with a final—*t, kokot,* in some places.)

In practically all parts of Polynesia, from Fiji to New Zealand, and Hawaii to the Paumotus, are found derivatives of either (1) or (2) or both, in the sense of 'claw, nail, hoof,' or 'to nip,' and the like. As these languages tend to drop final consonants, it is difficult to say whether such words belong to (1) or (2). But apparently they do not generally mean 'crab.' It seems reasonable to connect these words with the local names of the crab. Compare Malay *ketam,* 'crab,' but also 'to nip,' found in several languages from Sumatra to the Philippines.

I do not think the Arabic *khukhum* can be more than a fortuitous case of resemblance. I do not know it.

As for the relation of all this to *coco,* I fail to see how it can be accepted in view of the fact that the word occurs in Vasco de Gama's Roteiro (1498) and in the book of Barbosa (1516), both written before

Europeans got far enough east to reach the region where the cocopalm or nut is called *kuku*. The word seems to be quite European (Portuguese and Spanish)."

The coconut is of great antiquity in Ceylon, and earliest mention of it, Mr. Stockdale informs me, occurs in the "Mahawansa" in the reign of Dutthagamani, 101-77 B.C. Hsüan Tsang (II, p. 252), who travelled during A.D. 629-645, refers to coconuts in the Island of Na-lo-ki-lo (=Narakira—coconut=? Maldives), and says, "The people of this Island grow no grain but live only on coconuts." The Government Archivist of Ceylon also informs me that Sinhalese taxes on coconuts were in existence in pre-Portuguese times and were called *Pol watte-piediya* and *Polaya-panam* (*Pol*=coconuts in Sinhalese, *watte*=garden). In Yule and Burnell's "Hobson-Jobson," the passages quoted referring to the "Argell' or 'Great Indian Nut,' from Cosmas, the Monk, *circa* A.D. 545 or A.D. 547, and others lend further support to its Old World origin.

As opposed to the theory of the Polynesian origin of the coconut, Chiovenda holds the view that it originated in lands, now submerged, somewhere in the north-west of the Indian Ocean. He refers to Reinaud's records of the Indian, Albirunhi, in the eleventh century, who mentions the submergence of land in the region of the Laccadive and Maldive Islands, and of how the people of these islands when fleeing for safety, took their coconuts with them. He also refers to fossil Cocoineae, related to *Cocos*, having been discovered in Central Europe.

The fact that the early explorers found the coconut palm of very limited distribution in tropical America may be held to militate against its American origin and rather support the view that it was an introduced plant. Further evidence in support of the eastern origin of the coconut and also of its power to spread independently is afforded by the fact that several islands all grouped together bear the name Cocos Island or have a 'Cocos Bay.' These islands were apparently uninhabited at the time of their discovery and received their names no doubt owing to the fringes of coconut palms on their shores, as it was the tendency of the Portuguese and Dutch in the sixteenth and seventeenth centuries to name uninhabited islands by some distinguishing feature they presented.

Another fact which lends some support to the views of De Candolle, Beccari, Chiovenda, E. D. Merrill, and others, that *Cocos nucifera* is of eastern rather than American origin, is afforded by the recent discovery of fossil nuts of a *Cocos* in the Pliocene deposits at Mangonui, North Auckland, New Zealand. These have been named *Cocos zeylandica* by Edward W. Berry, and, though they are quite small, they show no marked features, except as regards size, to differentiate them from the existing genus *Cocos*.

O. F. Cook has taken infinite pains to try to prove that the coconut palm originated in South America, but many of his arguments may equally well be used in support of its Polynesian origin. With regard to the antiquity of the palm in America, he lays some stress on the finding of a carved coconut shell in a grave in the Chiriqui district on the Pacific coast of Panama. This bowl is figured in Cook's "History of the Coconut Palm in America," but it is not stated whether the grave was a pre-historic one or not. I am informed by the authorities at the British Museum that the design on the carved shell is certainly not aboriginal American, nor does it resemble anything from the East Indies at all closely. It is considered far more likely to be "a post-Spanish American product influenced by European designs, such as were used by Indians in many parts of America after the arrival of the white man."

The highly-polished coconut cups of Spanish South America are mentioned as a suggestive analogy, and also the similar floral patterns of modern Indian painted pottery, etc.; it is not thought that the carved shell

carries any weight as evidence either for or against the American origin of the coconut palm.

The fact of the finding of some particular bowl in a country needs some further support in the way of evidence, to prove that it may be a product of the country where it has been found, since a good deal of false deduction might be based on the finding of shells of the double coconut (*Lodoicea*), in India, where they are used as drinking bowls and for other purposes. Cook also attaches importance to the occurrence of coconut palms on Cocos Island, situated in the Pacific Ocean some 300 miles to the west of Panama, which since the coming of the Spaniards has not been inhabited and the coconut palms have almost disappeared. After considering the various suggestions made by Cook, there seems to be nothing against the view, held by De Candolle, that the coconut palms on this island might have been brought there by early Polynesian voyagers. From this island, or more possibly by the landing of some of these early voyagers on the Pacific coast of Central America, they became established on the mainland and were in the course of time carried far and wide.

Mr. H. C. Sampson, who carefully studied Cook's work, has kindly supplied me with the following notes :—

The three main points raised by Cook are :—

1. That the coconut must have plenty of soda salts for it to thrive. Therefore it must be a native of those parts of America where such alkali abounds in the soil.

2. That the coconut will not establish itself on a coast-line without the aid of man.

3. That the fibrous covering on the coconut is intended to hold a supply of moisture for the roots of the young seedling and not to act as a float.

As to 1. Coconut palms are able to stand a high percentage of soda salts in a soil provided there is very free drainage and aeration. Where these are absent the tree immediately becomes unhealthy. Tidal action on a sandy sea coast supplies the necessary drainage and aeration, hence trees on a sandy sea coast are usually healthy, while those facing a lagoon or backwater unhealthy. Health, according to Cook, is the ability to form fruit; but this is not so. Healthy trees need never bear fruit. They will, however, bear fruit if the necessary plant food is made available to them in the soil. Coconuts will grow quite well in soils deficient in soda salts. This has been proved by the Bombay Department of Agriculture, when the Government of that Presidency was considering the question of remitting the duty on salt required for the purpose of manuring coconut trees in the Konkan and in North Canara.

I myself have seen coconuts doing very badly on soils which were inclined to be alkaline, though the trees were afterwards made to bear heavily by breaking up the alkaline pan, which one usually sees associated with such soils.

With regard to 2. I have seen self-sown coconuts establishing themselves on the cays off Belize which are being formed in the shallow water. The young palms are able to compete for light with the young mangrove which under such conditions is inclined to remain stunted. The coconut groves on the east coast of Trinidad in the region of the Cocal are undoubtedly self-sown. These are said to have originated from the wreck of a French schooner laden with coconuts. One sees the trees growing in clumps often four or five together or in close proximity, which would not be the case had they been planted by man. That coconuts do not do this more frequently is due to two causes: First, that though the seed may germinate it cannot survive where the shore vegetation is

liable to overshadow the seedlings, and secondly, in the open glare of an exposed beach it is not possible for the husk to retain sufficient moisture to enable the young roots of the coconut to feed on the husk.

With regard to 3. It is very difficult to get coconuts to germinate in a dry climate without initial shade and constant watering. The fruit when it is ripe gives up its moisture from the husk, and it can only get this again by coming into direct contact with moisture either from the soil or from continual rain. Thus on the sandy coast soils of Ceylon and Southern India, seed coconuts have to be nearly buried in the sandy soil, which has to be kept continually moistened, and even under such conditions germination is much slower than it is in countries with a more evenly distributed and heavier rainfall.

It is clear that natural regeneration would be impossible for the coconut in a dry country such as Cook claims to be the natural home of the coconut. It seems to me much more likely that the coconut was taken to America by immigrants arriving there prior to the discovery of that continent by western civilisation than the reverse.

Turning now to the mode of dispersal of the coconut :—

The sight of the Cocos-Keeling Islands, or Atolls, in mid-ocean on the direct route from Ceylon to Western Australia, and some 700 miles to the south-west of Java and the Straits of Sunda, led me to look into the early history of these Islands and search for records of the occurrence of coconut on other uninhabited islands in the Pacific Ocean.

Coconut palms were well established on these uninhabited islands when Captain Le Cour visited them in 1825, before Captain Ross arrived there that same year, for he "carved his name on the palm trunks." H.P. Guppy brings together some very interesting evidence in connection with the coconuts growing on the Cocos-Keeling Islands. In a general map of the Eastern Archipelago, published in Amsterdam in 1659, they are named the Cocos Islands, showing that the coconut palm was then a feature of the group. Again, in Jan de Marre's plan of the islands in 1729, coconut palms are figured with the simple, yet probably unintentionally true, remark : "it would seem that Nature herself has produced these trees," and in 1753 Van Keulen described them as being wooded. Further, some fifteen or sixteen years before the islands were occupied, it is stated that they were "covered with trees, principally the cocoa-tree" (=coconut palm).

Charles Darwin visited the Cocos-Keeling Islands in the year 1836, some ten years after their rediscovery, and found them thickly covered with full-grown coconut palms. He points out that at one time they must have existed as mere water-washed reefs, and therefore "all their terrestrial productions must have been transported by the waves of the sea." It is also of interest that Darwin refers to the occurrence of *Birgus latro* on these islands, and this suggests that both coconut and crab were brought to the islands by the same means.

From this evidence it appears certain that the coconut palms on the Cocos-Keeling Islands were established there when they were uninhabited, and there is also strong probability that they were the result of ocean-borne nuts which had drifted there with many other seeds from the east, as Guppy points out. From information kindly supplied by the Hydrographer to the Royal Navy, I find that the general trend of the ocean currents in this region is from the east westwards, so that any flotsam and jetsam reaching the islands would tend to come from Java or Sumatra or from the Sunda Straits. It seems not unreasonable to assume that the original nuts which have given rise to the coconut groves on the Cocos-Keeling Islands reached there as ocean-borne nuts from the islands to the east, and

this supposition may be held to give some additional support to the view that the islands of the Eastern Archipelago of the Pacific Ocean should be regarded as the original home of *Cocos nucifera*.

It is, of course, true that young sprouting coconuts on the strand are constantly destroyed by the land crabs, but it seems not unreasonable to assume that a few nuts, out of the many which must have been washed ashore, would have been covered by drift sand and so protected from the land crabs, and that from those which successfully germinated the dense groves of coconut palms on these and on other uninhabited islands had their origin.

Wood-Jones mentions that water-borne coconuts can be seen germinating all round the lagoon shores of Cocos Islands, and adds there is "no reason to suppose that any human agency was involved in the first planting of the coconuts in Cocos-Keeling."

The coconut palms now growing in the Bay of Cocal, Trinidad, are reputed to have resulted from nuts washed ashore from a ship wrecked on the coast, and also as mentioned earlier, on some of the cays which are being formed off the coast of British Honduras self-sown coconuts may be seen. Coconut palms are also found on small rocky islets off some of the Fiji Islands, where evidently the nuts have been cast up by the sea and never could have been planted.

Guppy, in his paper on the Cocos-Keeling Islands, produces weighty evidence to show that the coconuts there must have been water-borne and have germinated when washed up on the strand. He also brings evidence in support of the contention that the coconut is able to germinate without human intervention when washed up on Fijian beaches, whether brought down by a river or transported by an ocean current.

Leguat in his account of the Island of Rodriguez says: "The sea having thrown us up some Cocos which began to bud, we planted some of the fruit some months after our arrival, and when we left the place the trees were four feet high." These nuts, he believed, came from the Island of Ste. Brande. There are also two islands called Coco and Cocos in this region.

A definite proof that the coconut will germinate unaided when washed ashore has been afforded in the case of the Island of Verlaten, which lies to the north-west of the Island of Krakatau in the Straits of Sunda, between Java and Sumatra. Verlaten Island, which is uninhabited and uninhabitable, was visited in April 1919 by Dr. W. Docters van Leeuwen, now Director of the Botanic Gardens, Buitenzorg, and he records with a photograph, the finding there of a coconut palm sprouting in the drift mud—an accretion of soil containing pumice stone—at only a few yards' distance from the sea. This proves conclusively that an ocean-borne coconut can germinate without human aid, as Beccari asserted, and refutes the opinion of Hugo de Vries, O. F. Cook, and others.

When I was in Java in March 1928, Dr. Docters van Leeuwen very kindly gave me prints of two photographs of two young coconut palms, similar to the one on Verlaten, which he found growing on the beach of the Island of Krakatau, which since the great eruption of 1883 has remained uninhabited. In one case the young palm is partly overgrown by *Ipomoea denticulata;* in the other, the palm is growing amongst the grass *Ischoemum muticum* and, despite the competition with other vegetation, they both appear to be holding their own quite successfully. These observations afford satisfactory evidence that ocean-borne nuts can germinate when washed ashore on an uninhabited island and become established without the intervention of human agency, and the evidence which has been brought forward may be considered to strengthen the view that the Polynesian or East Indian Islands are the original home of the coconut palm.

PANAMA DISEASE RESEARCH.*

[*The following is a brief summary of two reports recently submitted to the Empire Marketing Board on the writer's research on Panama Disease of Bananas at the Imperial College of Tropical Agriculture.*]

Introduction.—It is not always that the first outbreak of a disease can be traced with certainty. This is true of Banana Wilt Disease or, as it is generally called, Panama Disease. While it may have made its appearance in the Western Hemisphere for the first time towards the close of last century its wide distribution in the Old World suggests a much greater antiquity. It is worthy of note that the disease became noticeable, or at least was given attention, about the same time that the banana industry had commenced its rapid expansion. The important results to date regarding Panama Disease are the outcome of work by E. F. Smith, who named the organism and indicated its capacity for growth in the vascular tissues, Ashby, who isolated the organism and carefully described it in pure culture, and Brandes, who carried out detailed inoculation experiments whereby the pathogenicity of *Fusarium cubense* was conclusively demonstrated. This important work has been repeated by Hansford and Reinking.

For all practical purposes our knowledge of Panama Disease may be briefly summarised as follows: it is a Wilt Disease of great severity and is associated with the parasitic soil organism, *Fusarium cubense,* on suckers and roots. Several varieties are highly susceptible, but of outstanding commercial importance is the Gros Michel banana (*Musa sapientum*). While the various inoculation experiments described give a clear proof of the pathogenicity of *F. cubense* in no case do possible accessory environmental conditions, such as soil moisture, aeration, texture, acidity, humus and mineral supply appear to have been adequately considered. The several experimental records show great uniformity of method, namely, that sterilized suckers in containers of sterilized soil were inoculated with *F. cubense* and that proofs of pathogenicity after nine or more months were obtained. Thus while the beginning and end points of the experiment are usually described in detail the records contain no information regarding intermediate events. Further, there have been no detailed experiments to test whether the attacking power of the organism is influenced by modification of the various external factors. In our present state of knowledge, then, there are two definite points of view to be considered.

1. The disease may be due entirely to internal factors, *i.e.*, to genetic constitution which determines lack of resistance to *F. cubense.*
2. The disease may be due to predisposing external factors which adversely affect the health of the plant so rendering it susceptible.

The importance of genetic constitution in this particular instance has long been known since the Canary Banana (*Musa cavendishii*) the Lacatan, and others, will grow on land where the Gros Michel has already succumbed to disease. The point to be determined is whether this well-known susceptibility is constant for all external conditions or whether it is possible to delay or prevent disease by promoting (?) the bad soil conditions under which the plant is frequently grown. On general grounds there is much to be said for both points of view.

* By Dr. C. W. Wardlaw in *Tropical Agriculture,* Vol. VI, No. 7, July 1929.

On broad ecological grounds there are many reasons why possible external factors should receive careful consideration. Field evidence points to water supply and aeration as factors of very considerable importance. Thus there is very little disease in the Parish of St. Catherine's in Jamaica, and none in Columbia where the banana lands are irrigated, *i.e.*, where plants are growing under conditions of controlled soil moisture. On the other hand disease is of frequent occurrence on stiff soils in regions of high rainfall. Disease also occurs on open light sandy soils. Both of the latter allow of great variability in conditions of soil moisture.

On field evidence the second factor, soil aeration, is also likely to be important, since most of the untilled virgin soils, of compact alluvial or clay, suffer badly from mottling indicating lack of adequate ventilation.

In so far as *F. cubense* is mainly a wound parasite, usually entering through the cut end of the sucker, any wounding agency, such as weevil-borer (*Cosmopolites sordidus*) may constitute an important accessory factor. There is thus a very considerable justification for entering on an investigation of the influence of possible external factors.

It is not necessary to discuss in detail all the implications of a test case such as this *i.e.*, external *versus* internal factors, but it is clear that if it proves to be purely a matter of the hardihood of the plant as determined by genetic constitution then no effort should be spared to produce an immune banana to replace the Gros Michel. On the other hand should the disease prove to depend on the presence of some external soil factor susceptible of modification, then there will be a tendency in time, as determined by a number of economic factors, to make for progress in the treatment and improvement of tropical soils.

In investigating the parasitic attack of *F. cubense* on the banana there are two distinct, though interrelated pathological problems, namely, root infection and sucker infection.

Root Inoculation Experiments.—The first report is concerned with root inoculation experiments on which there has been hitherto only the briefest information. Several series of experiments are described. Actively growing roots from suckers placed in ventilated moist chambers when inoculated at the tip with cultures of *F. cubense* did not become diseased. The roots continued to grow vigorously so that the inoculum was left at some distance behind the apex. More slender roots sometimes showed a slight infection. Roots grown in unventilated moist chambers in which the carbon dioxide from the respiration of the sucker was allowed to accumulate were similarly inoculated at the apex. A different result from that recorded above was obtained. The apex became dark in colour, no further growth took place, and a basal cluster of rootlets grew out *i.e.*, the presence of the inoculum had the same effect as root pruning. Even under these conditions the parasitism was not complete and after some days a tardy but ineffective apical growth continued, while the lateral rootlets became diseased. Several inconclusive inoculation experiments are described. These two contrasted experiments then indicate that roots maintained in a healthy state are not attacked by *F. cubense*, and that CO_2 concentration is a factor in root infection.

Roots grown in moist chambers were decapitated and inoculated with *F. cubense*. A rapid die-back of the roots took place, the youngest roots showing the most rapid infection. This is in keeping with the fact that *F. cubense* is most important as a wound parasite.

The relation of diseased rootlets to the main root was examined in some detail. As the rootlet passes through the cortex to the stele, toxic substances from the fungal metabolism tend to diffuse into the cortex with

lethal effects on the cells. It was found, however, that this killing of cortical tissue by diffusion of toxic secretions from the rootlets was of limited extent, and was held in check by defensive reactions on the part of the cortical cells. The latter, stimulated by dilute fungal secretions, enlarged, divided by walls at right angles to the direction of diffusion of toxic solutions, and became suberised (*i.e.*, impregnated with cork). The barrier of protective tissue thus produced had a cambiform appearance and was definitely effective in checking the further advance of either the hyphae of *F. cubense* or their toxic secretions. Detailed examination showed that while the affected tissue was of dark colour, with hyphae in evidence, the cambiform layer and the tissues beyond were clear and translucent and free from invading hyphae. In no instance were hyphae observed to penetrate the suberised walls.

Relation of Soil Acidity to Root Infection.—In order to test whether root infection was related to soil acidity, alkalinity, or chemical composition, different soils were collected, sterilized, inoculated with heavy uniform spore suspensions of *F. cubense* and maintained at a constant state of moistness. Roots from sterilized suckers were allowed to grow down into the pots of soil. On examination of the pots after 15 days and 25 days, it was found that, although amply surrounded by *F. cubense*, the roots were without exception free from disease and quite unblemished. A definite proof was thus obtained that soil acidity and alkalinity, while very important in their effect on soil condition, are not, of themselves, direct factors in root infection. In so far as they influence soil conditions, they may, of course, be of great importance in root infection.

Variable Water-Supply and Root Infection.—Suckers potted in five different soils in 10-inch pots heavily inoculated with *F. cubense* were examined after 50-90 days' growth. The pots were watered daily from above and were supplied from below by standing in pans of water. The more sticky soils were intimately admixed with sand to provide ample aeration. Under such conditions of aeration and water supply, vigorous root formation takes place. A large number of roots, grown in several different soils, was thus available for examination. In all the pots the majority of roots and rootlets were white and turgid and free from infection. Diseased roots were found under two circumstances only, namely in the top inch of soil where occasional drying out takes place and at the pot sides, in the top half of the pot, where again drying out and heat scorch are liable to occur. In the lower half of the pot, where there is a supply of capillary water from below, the roots were uninjured, and again at the bottom where roots were growing in constant aquatic conditions there was also no disease.

In the two situations described, however, where soil moisture was liable to fluctuate, all stages of root infection were found. Here fungal penetration is closely associated with loss of turgor. Invasion of tissue varied from superficial blemishing to complete exploitation of the whole transverse plane of the root. In the latter event a slow dying back, accompanied by characteristic Panama Disease discolouration of the vascular system, was found. In roots where superficial penetration had taken place, as the result of physiological shock affecting the outermost tissues only, it was found that the further advance of the hyphae towards the stele was definitely held in check by the formation of well-defined suberised cambiform barriers. Diffusion of fungal secretions coupled with wound stimulus had induced reactions in the unspecialised cortical cells. These consisted of cell expansion, cell division by walls laid down at right angles to the direction of diffusion of toxic substances, and the complete suberisation of walls adjacent to the diseased tissue. Such suberised cambiform barriers were definitely effective in checking further fungal invasion,

and on no occasion were hyphae or their lethal effects observed inside this defensive barrier. A large body of evidence is submitted which indicates the extent of root injury under these conditions of variable soil moisture, and points clearly to the highly reactive nature of Gros Michel roots, when they are grown under conditions conducive to vigour and health.

In the work of previous investigators it is assumed, on scanty evidence, that Gros Michel roots have only to be exposed to *F. cubense* to become diseased. But this is not so. It has frequently been observed, for example, that many of the roots of a badly diseased stool, presumably growing into soil highly infected with *F. cubense* are free from disease. This has been found to be true even of the youngest roots produced from a badly diseased rhizome. Theoretically, according to previous assumptions, the roots should have become infected as soon as the tips came into contact with diseased soil.

Thus both field and experimental evidence point to the fact that infection of the roots of Gros Michel by *F. cubense* is definitely conditional and is referable to at least two factors that are of first importance in tropical soils. These are soil oxidation and variable water supply. Without entering into details it will suffice to mention that most untilled compact virgin tropical soils are highly mottled and stand in need of aeration. Roots growing in such soils have to contend with defective aeration. With regard to the problem of water supply it has long been known that in regions of irrigation, *i.e.*, of controlled soil moisture, the incidence of Panama Disease is at its minimum.

This investigation by no means exhausts the interesting problem of root infection. The broad conclusion which has been reached is that root infection, while important in the physiology of the plant as a whole, is of lesser importance. The fundamental problem in banana wilt is that of sucker infection.

Observations on Sucker Infection.—The second report is concerned with observations on sucker infection. In the inoculation experiments of previous investigators, while definite proof of the pathogenicity of *F. cubense* to Gros Michel has been obtained, their memoirs contain little information regarding the behaviour of the attacking organism when brought into contact with its host. In none of the papers is there detailed evidence regarding the nature or rate of infection, the state of the sucker from time to time, or the influence of possible external factors. In short, one is left with the impression that the sucker has only to be exposed to the organism to become diseased, and that the infection is rapid, straightforward and unimpeded. But general experience indicates that, almost without exception, the analyses and detailed study of the several important Wilt Diseases are both complicated and variable. These remarks are true also of Panama Disease.

In a series of preliminary experiments the writer set out to investigate the behaviour of the sucker during the early stages of inoculation and to determine the nature and rate of fungal penetration. Those experiments have proved exceedingly useful and important and have brought to light a mass of data hitherto unrecorded.

Inoculation of Suckers in Moist Chambers.—Superficially sterilised Gros Michel suckers were inoculated at the cut basal end with cultures of *F. cubense*. The suckers were then placed in 4,000 cc. closed containers, kept suitably moist, and examined after 10 to 25 days. The infection thus proceeded in an atmosphere of carbon dioxide from the respiration of the suckers. It was found that a noticeable amount of penetration took place in 10 days. The tissue was affected to a depth of 1 to 1.5 cm. At this stage the infection was found to be what may for convenience be described

as a *mass infection,* in contrast to its later stages when it is generally found as a *vascular infection.* Even at this early stage in some suckers it was observed that, passing out from the region of mass infection, there was vascular strands showing the characteristic yellow and red discolouration typical of Panama Disease. The region of mass infection was dark in colour, and consisted of two zones, firstly, a zone invaded by hyphae, and further in a zone where the tissue had been killed in advance of the hyphae by the diffusion of lethal by-products of fungal metabolism. The suckers of the immune Canary banana inoculated under the same conditions showed only slight infection. Further experiments showed that in both Gros Michel and Canary suckers penetration was most extensive in young suckers or in meristematic tissue. These observations were useful in indicating the extent and nature of parasitism when the suckers are in a relatively passive state. Under the same experimental conditions it was possible to induce a considerable amount of infection in young suckers of the immune Canary banana.

Reaction to Infection.—In these experiments on Gros Michel suckers it was found that after 25 days' infection, the amount of mass penetration was not as great as might have been expected. Detailed observation then revealed the fact that further penetration by the fungus was being held in check by reactions developed in healthy tissue outside the zone of killing. It was found that certain cells enlarged, acquired a prism-like shape, divided by transverse walls at right angles to the direction of diffusion of toxic fungal secretions, and became suberised. In fact a protective barrier, not unlike a cambium, rendered impervious by the deposition of suberin (cork) in the outer walls, had been formed in response to fungal invasion. It is well known that such cambiform formations are very uncommon among the monocotyledons. These changes are accompanied by the removal of storage starch from the reacting tissue.

The Influence of Fungal Secretions.—Having shown that killing takes place in advance by the diffusion of lethal secretions from hyphae growing in banana tissue, and also that certain protective reactions take place in the sucker itself, the next stage was to test directly the effect of staled fungal solutions.

Freshly-cut suckers were therefore placed in several culture solutions in which *F. cubense* had been grown for 20 days. On examination after four days it was found that the suckers had reacted to the fungal secretions present in the solutions (from which hypae and spores had been filtered off) by forming a suberised cambiform barrier comparable to that already described. It was found that the reaction of young tissue was much greater than that of more adult tissue.

Reaction of Suckers to Wounding.—Suckers of Gros Michel, Canary (Governor) Lacatan and Red bananas were wounded at several points and planted in potting compost in which *F. cubense* and other soil fungi were present. After ten days it was found that the suckers of all four varieties had reacted to wounding and initial fungal penetration by the formation of more or less well-defined suberised cambiform barriers. Deeper fungal invasion was effectively held in check by this means. As before it was found that meristematic tissue was much more highly reactive than adult tissue, the cambiform cells having sometimes six to eight transverse divisions. A detailed comparative account of the reactions of the four varieties is given.

Penetration of F. cubense into Growing Suckers.—A collection of soils in 10-inch pots covering a pH range of 5·8 to 8·1 heavily inoculated with *F. cubense,* was planted up with Gros Michel suckers. The soils were not sterilised so that in addition to *F. cubense* the normal fungal flora was present. A silt soil, on which Panama Disease notoriously occurred, with

pH 6·4, was used in this experiment for purposes of comparison. As some of the other soils were of a sticky intractable consistency, about 30 per cent. of sand was intimately admixed. Suckers set in pots of these soils, with uniform daily watering, may be regarded as growing under physical conditions conducive to vigour and health. Altogether some two dozen suckers, grown under such conditions for periods of 50 to 110 days, were examined in detail. In all the soil mass invasion of the cut basal ends of the suckers was found to be limited in extent, and less in amount than that produced in closed moist chambers (where CO_2 accumulated) in one-third of the time. Vascular infection was also found to be extensive. Again, in all the suckers examined the infected tissue at the cut basal end was found to be bounded by a well-defined suberised cambiform barrier. Thus in the first two to three months of exposure to *F. cubense* under the healthy conditions of pot culture the amount of penetration was singularly little. Without attempting to prejudge the final results of inoculation after six to twelve months these observations provide a definite record of the tardy initial penetration under the conditions of the experiment. These observations are not in keeping with the experimental results of Brandes who found that several young plants growing in inoculated soil were severely stunted almost from the start.

In the report a detailed account of the development of the cambiform barrier and the suberisation of the outer walls is given. The infected tissue was brown in colour, dead, and richly infested with fungal hyphae. The cambiform tissue appeared as a clear hyaline layer bounding the infected spongy tissue. Inside the cambiform layer was the normal, white, starch-filled storage tissue. The cambiform cells sometimes had eight to twelve transverse septations. The presence of suberin in the outer walls of the cambiform layer was demonstrated by various staining reactions and also by placing sections in concentrated sulphuric acid when all the cellulose tissue was dissolved away leaving behind a skeleton of suberin. The presence of suberin (*i.e.*, cork material) in the cell walls renders the latter impervious to liquids and gases. This substance therefore not only checks the further penetration of hyphae, but also prevents the further diffusion of lethal fungal secretions. In no case was penetration of the cambiform barrier by hyphae observed, or the discolouration and killing of the component cells by the diffusion of toxic secretions. The efficacy of the defensive mechanism is thus clearly proved.

It was sometimes observed, however, that cells which were in the act of expanding to form cambiform tissue were overtaken by toxic secretions before complete suberisation of the walls had taken place. Such cells were killed and afterwards invaded by hyphae. There is thus an interesting race between the protective reactions of uninvaded tissue and the diffusion of lethal secretions from infected cells further out. In some suckers it was found that two cambiform barriers were formed before the fungal invasion was completely checked.

Penetration into the Vascular Strands.—In its later stages, Panama Disease is over and above all significant as a vascular disease. This is true of most Wilts caused by *Fusaria*. In the sucker inoculations described in the previous sections it has been seen that the unspecialised parenchymatous tissues of cortex and stele resist the mass invasion of *F. cubense* by the development of an impervious suberised cambiform layer, the efficacy of which has been confirmed by detailed examination of a large amount of material. This barrier, however, is complete in so far as it is traversed by longitudinally directed vascular strands. Once hyphae gain access to the wood-vessels they may traverse long distances unimpeded by transverse septæ, and it is as a vascular parasite that the fungus is usually recongnised in both the sucker and aerial pseudostem.

Most authors by inference suggest that the fungus is in its most favourable surroundings in the wood-vessels, and that, in attacking a root or sucker, invasion of the xylem might be regarded, speaking teleogically, as the objective. Whether this is the true interpretation or not remains to be seen. If recent theories regarding the paucity of foodstuffs in the wood-vessels are correct, one is led to speculate on the reason why hyphae should leave well stocked cortical cells for the scanty food supply in the vessels. It might be mentioned at this point the hyphae in the vessels are mostly unbranched, slender and attenuated, suggestive of growth under adverse conditions. If the amount of foodstuffs in the vessels is small, it also follows that the by-products of fungal metabolism, *i.e.*, the staling products, or toxic secretions, will also be proportionately small in amount, and it becomes a question whether toxic substances from this source alone are responsible for the major Wilt symptoms in the adult plant. A more likely suggestion is that mass infection, developed in the storage parenchyma, where large quantities of starch, protein and cell sap materials are available for active fungal metabolism, is the source of the considerable quantities of toxic substances required to produce the major Wilt symptoms. The elimination of such regions of mass infection by the formation of protective barriers developed in suckers grown under favourable conditions is regarded as important. The experimental evidence shows that where vascular strands pass out from limited zones of mass infection, only slight and localised discolouration is the rule.

Diseased vascular strands which had passed through the cambiform layer from the small outer zone infection were examined in detail. The presence of fungal secretions and of hyphae in the wood-vessels, and the diffusion of toxic substances from them into the adjoining vascular and ground tissue, was found to have induced a number of growth activities. Cambiform barriers developed in the ground parenchyma at right angles to the direction of diffusion from the vascular strands. In some of the vascular strands themselves additional changes were observed. The living parenchymatous cells abutting on the vessels had elongated, divided by transverse walls, and, in fact, formed a typical cambiform barrier round the diseased vessels. Suberisation took place on the walls of the cambiform layer adjacent to the vessels. Examination of other material showed that any of the unspecialised vascular parenchyma cells were capable of taking part in the formation of such cambiform barriers. The reacting cells invariably elongated parallel to the drection of diffusion from the vessels, and divided by transverse walls at right angles to the direction of diffusion. Suberisation of walls was invariably towards the source of the lethal solutions.

We thus arrive at an interesting contrast. In superficially infected roots structural and biochemical changes are brought about by living tissues to keep the fungus out of the vascular strands, while in the sucker, where hyphal penetration of the vascular strands has been effected through the cut ends, comparable changes are made by living tissues to confine the fungus and its toxic solutions within the wood-vessels.

These observations, then, go a long way towards explaining why the fungus does not escape from the wood-vessels. The importance of the physiological state of the sucker tissues, and consequently their reactive powers, which are closely related to conditions of growth, is indicated by such observations.

Inoculation of Gros Michel Suckers in Presence of Weevil-Borer (*Cosmopolites sordidus*).—Twelve healthy young Gros Michel suckers were inoculated on the cut basal end with a central inoculum of *F. cubense*. These were planted in three large boxes of soils of different pH value, the original idea of the experiment being to determine whether there was

any relation between the amount of infection and soil acidity. In all three boxes, after 80 days, some of the plants showed preliminary Panama Disease Wilt symptoms while others had good foliage colour, and appeared to be perfectly healthy. The suckers were taken out and examined in longitudinal section. In the healthy suckers it was found that only a shallow penetration had taken place at the inoculated end. Further infection had been checked by the formation of a well-defined cambiform layer. Vascular infection was inextensive.

When the diseased suckers were examined, however, it was found that the stele showed the characteristic yellow and red vascular discolourations. These extended to the meristem and passed out into the leaf-bases. On closer examination it was observed that this well-marked infection had not originated through the inoculated basal cut surface. At the latter point the fungus had effected only a comparatively shallow penetration as before, and also had been definitely held in check by a cambiform layer. A more detailed examination then showed that the major vascular infection originated at the neck of the sucker about soil level and proceeded upwards to the meristem and leaves and downwards to the basal end. In most of the suckers this was clearly proved by the fact that the downward infection had not yet reached the cut basal end. Further investigation showed that all the diseased suckers had been invaded by Weevil-borer (*Cosmopolites sordidus*). The larval burrows could be traced from the outside inwards and the disposition of tissue affected by *F. cubense* coincided with the extent of the burrowing. Apparently in these suckers the hyphae of *F. cubense* had followed the paths of the larvae. The damage caused by the latter to vascular strands and ground tissue, together with the considerable quantities of food materials made readily available for the hyphae, would create a large zone of mass decay from which an extensive amount of vascular infection would inevitably result.

In another experiment Gros Michel suckers had been grown in pots of unsterilized soil from a badly infected area on the College grounds. The soil had been further infected by heavy spore suspension of *F. cubense*. After 115 days four pots showed characteristic external symptoms of Wilt. When the suckers were examined in longitudinal section it was found that the cut basal ends were completely protected by well-developed cambiform barriers, and that vascular infection had not originated from this source. The marked vascular discolouration in the middle and upper portions of the suckers was again definitely associated with larval burrows.

All varieties of bananas are liable to be attacked by weevil-borer. When the Gros Michel banana is attacked with *F. cubense* present, the result is a very effective parasitism by the fungal organism. Without elaborating this point further it is evident that the parasitism of *F. cubense* in the presence of weevil-borer merits the most careful attention.

Lateral Infection of Suckers.—As *F. cubense* is principally a wound parasite, two possible points of entry into the sucker, in addition to the cut basal end, remain to be considered. These are (a) leaf bases of old leaves and (b) root bases exposed by trimming off roots at the time of planting.

It was found that infected leaf bases were bounded internally by a characteristic suberised barrier of cambiform tissue. Invasion through these exposed surfaces is therefore checked.

When roots are trimmed away from the sucker, each root base presents a wounded open surface, and theoretically invasion of the sucker through the vassels of the root should take place rapidly. Observations conducted on a large collection of suckers growing in infected soils, however, have shown that infection of the sucker does not take place through these points of entry, and there are therefore strong indications that some effective protective mechanism is in operation.

It has already been seen that unspecialised tissues may become structurally modified and suberised so as to prevent further fungal invasion.

The great obstacle to be overcome by the plant is the blocking of the wide wood-vessels to prevent the further passage of hyphae and their toxic secretions. It was found in the root bases that this difficulty was overcome in two distinct ways, and frequently both were present in the same cross section. These were, (1) by tylosis, *i.e.*, the intrusion of living tissue through the pitted walls of the vessel and subsequent enlargement of the tyloses inside. These tyloses become closely adpressed and suberised, and prevent further penetration of hyphae or diffusion of lethal solutions; (2) by vessel collapse; dilute solutions of the fungal secretions have a stimulating action on living cells; those abutting on the vessels expand considerably and bring about a complete collapse of the vessels.

Discussion.—These reports have been concerned with a statement of facts regarding preliminary experiments on the inoculation of roots and suckers rather than with the final implications of such observations and findings. The extent of an infection which normally may take a year to run its course in the field cannot be prejudged on observations limited to the first few months of exposure to the parasitic organism. Collectively the results obtained so far show that despite the virulent parasitism attributed to *F. cubense,* inoculated suckers grown under conditions of uniform moisture and adequate aeration resist fungal invasion by defensive structural and biochemical modifications. Such growth reactions are always in definite relation to the source of infection. Where mass penetration is shallow, vascular infection has also been found to be significant. These observations are, of course, set down without prejudice to greater degrees of infection that may be found during later phases in the metabolism of the sucker and the life of the plant as a whole. The results obtained are simply records of the limited parasitism found when suckers are maintained under controlled conditions favourable to healthy growth.

In dealing with the influence of external factor on sucker infection at least two are indicated as being of considerable importance, to wit, carbon dioxide concentration and injurious agents such as weevil-borer.

In conclusion, while the evidence submitted in these reports indicates that the intensity of the infection and the power of the plant to react are conditioned by certain external factors, it would be unwise to prejudge final results on preliminary findings. The importance of the observations recorded lies, rather, in that they indicate the lines of research and methods that will be most profitable to follow, and at the same time they afford a definite series of criteria by which the activities of invading parasitic organisms may be gauged.

LIMING OF TROPICAL SOILS.*

Introducton.—While it is generally admitted that the agricultural land of temperate countries owes much of its maintained fertility to the frequent dressings of limestone, chalk or marl which have been applied to it in the past, yet it is only recently that the problem of liming the cultivated soils of the tropics has received the attention which it merits.

It is evident that a tropical soil, subjected as it is to more intense leaching consequent upon the higher rainfall occurring in the tropics and lacking in the majority of cases the beneficial effects of crop rotation, is prone to become more rapidly deficient in lime than in a soil occurring in a temparate zone.

In 1927, Hardy, who was studying the general soil conditions occurring in the sugar-cane lands of Trindad in relation to the susceptibility of canes to blight consequent upon froghopper attack, showed that, in general, soils possessing an alkaline reaction supported canes which were resistant to froghopper blighting, while canes growing on soils of acid reaction were susceptible to blight. This discovery naturally proved an incentive to the further examination of sugar-cane soils in regard to their lime status and a considerable amount of interesting data bearing upon this question has been collected by the Scientific Committee of the Froghopper Investigation.

The object of this article is to give a short account of the conclusions which have been drawn from this work and at the same time to discuss possible means for the promotion of an efficent programme for an estate liming campaign.

The Objects of Liming.—It would be as well, primarily, to describe the main beneficial effects which are brought about when an application of lime is made to a lime deficient soil.

They are (1) the amelioration of the physical properties of the soil, its tilth, etc., (2) the correction of soil acidity, (3) the provision of lime as a plant nutrient.

In considering the beneficial effect of lime upon the physical properties of a soil, upon its tilth and its general field behaviour, it is necessary to have an idea of the modern conception of the composition and properties of the soil.

The finer particles occurring in a soil are those which impress their properties upon the soil as a whole. They are the clay, the fine silt and the humus fractions. A soil containing but a small proportion of these finer particles is sandy and light, a soil possessing a large proportion is clayey and heavy. These finer particles may be likened to small sponges. They have the property of expanding and absorbing water when wetted and of shrinking upon drying out. These small particles further possess the property of loosely holding or 'absorbing' at their surface metallic. or in some cases acidic, *ions.*

It is obvious that there is an upper limit to the number of ions that a soil particle may absorb upon its surface. When this upper limit is reached and the whole of the absorptive power of the soil is satisfied with metallic ions the soil may be said to be 'saturated.' The total absorptive capacity of a sandy soil containing a few of the finer particles will naturally be relatively small, that of a clay soil containing a large proportion of finer particles will be relatively large.

* By R. R. Follett-Smith, B.Sc., A.R.C.S., in *The Agricultural Journal of British Guiana*, Vol. II, No. 2, June 1929.

These absorbed ions held by the soil particle are mainly confined to hydrogen, calcium, magnesium, potassium and sodium. In neutral soils calcium comprises some 80% of these ions.

The work of Joseph and Oakley in Egypt has demonstrated that it is upon the nature of these absorbed ions that the physical properties of the soil particles, and consequently of the whole soil, depend. If, for instance, there is a preponderance of sodium ions absorbed upon the soil particle surface, a condition likely to occur where the soil is periodically inundated with sea water, the soil itself tends to be very sticky, it shrinks upon drying, it is relatively impermeable, its particles are well dispersed, it attains a relatively high density after shrinkage, and it is difficult to work. If, on the other hand, the majority of ions absorbed at the soil particle surface are calcium then the particles are well aggregated, the soil is less plastic, it shrinks to a lesser degree on drying, it is more permeable, it attains a lower density after shrinkage and it is easier to work. The absorbed calcium ions appear to confer waterproofed effect upon the soil particles.

It is clear then that the application of lime as an ameliorant of the defective physical properties of a soil aims at the replacement of other ions at the soil particle surface by calcium ions.

It must be pointed out that the *absolute* amount of calcium ions absorbed at the soil particle surface is no measure of its effect upon the physical properties of the soil particle for it is evident that a light sandy soil, possessing a relatively low total absorptive capacity, will be satisfied with a smaller amount of absorbed calcium than would a heavy clay soil, possessing, as it does, a much larger total absorptive capacity. Absorbed calcium, in its relation to the physical properties of the soil, may be more usefully measured if the actual amount absorbed be stated as a percentage of the total absorptive capacity of the soil.

It has been shown by Turner that Trinidad cane soils, which are less than 60 per cent. saturated with respect to calcium, support canes which are regularly blighted by froghoppers, whereas those soils supporting canes resistant to froghopper attack approach a point of complete calcium saturation.

Experiments by the writer upon the metabolism of the sugar-cane show that canes growing in calcium-satisfied, alkaline soils are more *efficient* plants than those growing in an acid, calcium-deficient environment.

It is apparent then that only when approximately 80 per cent. of the total absorptive capacity of the soil is satisfied with respect to calcium will the soil possess a good tilth and desirable general physical properties.

The correction of soil acidity by the application of lime may prove beneficient in several directions.

The general term of soil acidity may be sub-divided into:—

(a) *Mineral acidity,* an effect due to the continued leaching of the soil by natural waters. Such a condition may affect sandy well-drained lands and usually occurs in soils containing little organic matter.

(b) *Organic acidity,* which occurs in badly-drained soils containing relatively large amounts of humus.

The adverse nature of an acid soil environment upon the plant may be due to the harmful effect of the acidity itself upon the plant or to the toxic effects of iron and aluminium which are known to become available in soils possessing an acid reaction, or to the effect of the acid environment upon the soil bacteria. These factors are operative at one and the same time in soils suffering from "sourness" and the relative importance of each is a question which is still at the controversial stage.

It is known that the micro-organisms responsible for cellulose breakdown thrive best of all in neutral or slightly alkaline media. One of the characteristics of a sour soil, undisturbed by cultivation, is the appearance of a mat of dead vegetation upon the surface of the soil consequent upon the diminished activities of micro-organisms. Nitrification, too, proceeds more rapidly at neutral reaction. Azotobacter, an organism responsible for the direct fixation of nitrogen, is very intolerant of acid conditions (below pH 6·0). The bacteria of legume root nodules are also sensitive to acid conditions.

Again, certain plant disease organisms are known to exist only in soils of acid reaction. A typical example of this may be cited in the case of the 'finger and toe' disease affecting turnips, etc. in the northern counties of England and caused by bacteria which thrive in soils of reaction between pH. 3·7 and 6·6 but cannot exist in soils possessing an alkaline reaction. The Panama Disease of bananas and the Rosellinia Disease affecting limes and cocoa may well be cases of this sort.

The question of the availability of aluminium and iron in toxic amounts in soils has received attention from many workers. Magistad concluded that soils whose reaction values lie with the range pH 4·7-8·5 do not contain aluminium in soluble form and are therefore not toxic to plants. The range of immunity stated above is probably wider than that found in actual practice since it is by no means certain that absorption by plants is confined to the soluble form defined by Magistad. The solubility effects of organic acids present in the soil upon aluminium and iron must also be considered.

Work upon the occurrence and effects of aluminium and iron in crop plants has been carried on by Hoffer and Carr in America working with maize and in Hawaii by McGeorge who examined sugar-cane.

Hoffer and Carr found that iron and aluminium accumulated at the nodes of maize growing on fairly acid soils (pH. 5·6-6·2). Continued aggregation of these metals finally led to tissue breakdown and predisposed the plant to root-rot. McGeorge working on the acids sugar-cane soils of Hawaii made similar observations. He puts the limit below which available aluminium is present in the soil in toxic amounts at pH. 5·8-6·0.

Other authorities suggest that the true toxic effect of aluminium is caused by the condition of impenetrability to nutrients conferred upon the root hair membrane by absorbed aluminium.

The definite conditions governing the availability of iron and aluminium in soils and the precise mechanism of the toxic effect of these elements are not yet clearly defined. Suffice it to say that a plant, growing on a soil whose reaction approaches neutrality, will not exhibit any of the characteristics of aluminium toxicity.

It has been suggested that the hydrogen iron is the chief toxic factor inhibiting growth in acid soils and this may well be the case in those soils where the reaction is such that available aluminium and iron does not exist. It is possible too that the colloids composing the surfaces of the root hair membranes may be adversely affected by an acid soil environment. Their physical properties may be so altered as to affect their permeability to plant nutrients.

The probability that a plant growing on a "sour" calcium-deficient soil is suffering from a lack of calcium as a plant food must not be overlooked.

The relative importance of all these inhibitory factors which occur within a "sour" soil has yet to be defined and could only be found for a particular set of conditions by direct investigation.

It is clear, however, that these conditions which restrain plant growth upon acid, lime-deficient soils may be counteracted by an adequate application of limestone.

The Source of Lime.—The question of the most suitable form in which calcium may be applied to the soil has long been a source of discussion. The efficiency of liming depends largely upon the extent of the surface area exposed by the material applied. The surface area exposed depends upon the degree of sub-division of the dressing applied. One ton of limestone ground to pass a hundred-mesh-to-the-inch sieve will possess a surface area ten times as large as will one ton of limestone passing only a ten-mesh-to-the-inch sieve. The degree of sub-division of the dressing is therefore of paramount importance with regard to its efficiency.

Burned lime and slaked limestone were formerly preferred to ground limestone as a source of lime chiefly on the score of their more finely divided condition. With the introduction of improved pulverising machinery it is now possible to obtain ground limestone in a finely divided state and any preference which may have previously been held for the use of quicklime or of slaked lime on the score of its greater sub-division has largely disappeared. In fact, the only information at present possesed as to the comparative value of these three sources of lime as an ameliorant of the physical condition of tropical soils definitely favours the use of pulverised limestone. Turner has had the opportunity of examining the soil conditions obtaining in an estate experiment designed to compare the efficiency of the different sources of lime and has shown that a dressing of ground limestone was the only application which produced a significant increase in the yield of cane and a definite rise in the degree of saturation of the soil with respect to lime.

There are also several practical considerations which favour the use of pulverised limestone. It may be stored indefinitely without fear of deterioration and it may be easily applied with the minimum of discomfort.

Limestone Specification.—While no definite specifications have been laid down with regard to pulverised limestone, it is agreed that it should contain not more than a small amount of magnesium carbonate and that it should be finely divided. On the other hand difficulty in application may be experienced if too great a state of sub-division is obtained. The following conditions will perhaps best define the product to be recommended :—

(1) That all the materials should pass through a seive of 10 meshes to the linear inch.

(2) That fifty per cent. of it should pass through a seive of 100 meshes to the linear inch.

Application of Limestone.—Not only should the soil particles be saturated with respect to calcium but the soil itself should contain a reserve of calcium carbonate if optimum conditions of soil tilth are to be maintained. Any restitution of calcium at the soil particle surface will be carried on at the expense of this reserve. If this store of lime is exhausted the degree of saturation of the soil with respect to lime progressively diminishes and by reason of the impaired permeability of the soil a large dressing of limestone may take a comparatively long time to effect improvement. It is obvious therefore that the calcium status of a soil should be maintained by periodic small dressings of lime. With an originally unsaturated soil however, experience has shown that a single relatively large application of lime will produce more immediate results than will small annual dressings.

In view of what has been said with regard to the relative impermeability of heavy soils unsaturated with respect to lime, it follows that all possible care should be taken to make the incorporation of lime and soil as complete as possible. Experience in Trinidad has shown that dressings of limestone did not penetrate to any extent below the level to which the soil was worked.

Duration of Effect.—Little information is available as to the probable duration of the effects of an application of limestone to tropical soils. Such a question depends upon the interplay of various factors chief among which are the thoroughness of the application, the texture of the soil, the rainfall and previous manurial treatment. Heavy soils will retain their lime content for a longer period than will light sandy soils. Since tropical soils undergo a more intense leaching action, consequent upon the heavier rainfall, than do soils of the temperate zones it seems probable that the duration of effect of limestone application in the tropics will be shorter than that experienced on soils of temperate countries.

Initiation of Liming Programme.—It is hardly necessary to point out that the initiation of an estate liming programme should be preceded by a thorough examination of the lime requirements of the estate's soils. Further, yield responses should be correlated with periodic laboratory examination of the treated soils in order that the soil chemist may confidently predict the performance of the soil consequent upon the application of limestone dressings.

It would not be out of place to mention at this stage a few of the indications characteristic of soil unsaturated with regard to lime and enumerate a few of the methods of use in the exploration of the lime status of soils.

A soil unsaturated with respect to lime cracks badly upon drying out. The dried-out soil possesses relatively great mechanical strength, it does not readily crumble. It has been noticed in Trinidad that nut grass thrives upon alkaline calcium-satisfied soils but fails to establish itself upon acid, calcium-deficient soils. It may be noted in passing that McGeorge has demonstrated the toxic effects of aluminium upon nut grass.

Of the qualitative laboratory tests which may be applied perhaps the most simple and useful is that suggested by Comber. It has been applied to cane soils and it is to be recommended in that it requires no special equipment and that the reagent covers the range of reaction likely to be met with in soils.

The use of indicators such as brom-thymol blue, phenol red, chlorphenol red and brom-cresol green for measurement of soil reaction is difficult of application and yields but rough figures as a result.

The employment of the quinhydrone electrode in spite of the somewhat expensive nature of the apparatus is much to be preferred in soil reaction studies. The method has many advantages over the colorimetric methods chief among which are the rapidity with which soils may be examined and its relatively high degree of accuracy. It should be noted that it becomes inaccurate when called upon to measure reactions more alkaline than pH 7·8 and that it does not yield reliable results in the examination of soils contained in small amounts of manganese. These conditions, however, are likely to occur in few, it any, of the cultivated soils of the colony.

Of the methods available for the determination of the lime requirements of soils perhaps the most useful is that proposed by Hardy and Lewis. Among its advantages are its simplicity and its rapidity (as many as twenty-five soils may be examined during a working day). The possession of a quinhydrone electrode outfit, however, is necessary.

SUMMARY.

Work in Trinidad has demonstrated that the lime status of soils which are subjected to intense leaching and upon which no system of rotation is practised is a question of paramount importance and should receive ample consideration prior to the formation of a manurial campaign employing other mineral fertilisers.

The above article describes the beneficial effects to be obtained by an adequate application of limestone to calcium-deficient soils. It also outlines the deleterious factors operating upon crop plants growing in acid soil environments. In the light of work recently carried out in Trinidad the use of pulverised limestone as a source of lime is advocated. A specification for pulverised limestone is described. The application and duration of effect of dressings are discussed. Laboratory methods applicable to the study of the lime status of soils are suggested.

NEW EMPIRE INDUSTRY.*

TUNG OIL.

THE production of Tung Oil in Ceylon, a valuable raw material used in the manufacture of paint and varnish, is to be assisted by the Empire Marketing Board. Grants have been made to the Royal Botanic Gardens, Kew, for the distribution of Tung Oil seed in Empire countries, and to the Paint and Varnish Research Association for an investigation into the chemical and technical properties of the oil. Some time ago the Imperial Institute set up a Tung Oil Sub-Committee to foster Empire protection of the oil, and the Empire Marketing Board's grant follows this Committee's recommendations.

Until very recently China was practically the sole supplier of the Tung Oil requirements of the world. Its use during the war in the manufacture of certain water-resistant varnishes which were needed for aeroplane work first brought its importance to the fore.

Great Britain is still almost entirely dependent on China for supplies. In 1927 China exported 2,659 tons direct to this country, but nearly three times this amount was exported to Hongkong, and a large percentage of this found its way to Great Britain. Whereas there is a steadily increasing demand for the oil, the supply is very unlikely to increase and is both fluctuating and irregular in quality. There is a clear case, therefore, for the development of its production in the overseas Empire.

Experimental cultivation trials which are in progress in twelve of the Dominions and Colonies have already shown that Tung Oil does exceedingly well in many parts of the Empire. Experiments in Kenya in particular indicate that this Colony, and possibly other parts of Africa, are ideally suited to the growth of the Candle Nut Tree, as it is also called. Trees planted in 1922 at 5,500 feet have yielded fruit which has given a most satisfactory analysis. More seed was sent out from Kew in 1928 and Dr. Jordan says that Tung Oil is now being watched everywhere from Kenya to the Cape—Nyasaland, Tanganyika, the Rhodesias, Transvaal, Natal, Cape Province and Nigeria.

KEW A SEED BROADCAST CENTRE.

Experiments were started some years ago in India, Ceylon, Malaya, Burma, Kenya, Hongkong, Tanganyika and South Africa. In 1919 plantings were begun in New South Wales, and there are now about 1,000 trees under plantation in this State yielding satisfactory oil. Seed was sent by Kew in 1928 to a number of countries, including India, Ceylon, Cyprus, the West Indies, Jamaica, Bermuda, Palestine, Australia and New Zealand. The purpose of the grant to Kew is to encourage the continuance of this seed distribution, and to buy fruit for experiments on decortication and oil extraction which are to be undertaken by a cake mill firm.

The Paint and Varnish Research Association will make a comparative study of the technical properties of Chinese, American and Empire-grown Tung Oil. Supplies of the latter for test will be received shortly from Kenya, New South Wales, Hongkong and possibly India. There are various

* Supplied by the Empire Marketing Board.

other problems which the Association will tackle. Two species of Tung Oil tree are at present known, and 90 per cent. of the commercial oil is derived from one of them. Certain experiments have indicated that the other variety, which is less hardy but quicker maturing, may prove more suitable for cultivation in Empire countries. It is possible, however, that this variety yields an inferior oil, and it is absolutely necessary to find out whether it is equally suited to manufacturers' purposes before its cultivation can be recommended.

A NEW KIND OF CAKE.

It is also possible that further research will indicate additional uses for Tung Oil; for instance, it may play a part in the manufacture of linoleum. The value of cake made from the residue after extraction of the oil is also to be investigated. It is possible that a new agricultural feeding stuff may arise out of the industry. Professor F. C. Drummond of University College, London, is to experiment with the cake on small animals, and this will be followed up, if sufficiently promising, by tests on farm animals.

Tung Oil fruits contain a high percentage of oil and compare very favourably with linseed and cottonseed. The kernels contain about 58 per cent. oil by analysis and yield in practice about 40 per cent. About 6 lb. of fruit give 1 lb. of oil. The trade is considered very profitable by the Chinese, whose methods of production and extraction are still primitive, and it is probable that, if Tung Oil were grown on plantation lines, an improved yield of both fruit and oil would bring in a handsome return to the grower.

MEETINGS, CONFERENCES, ETC.

BOARD OF AGRICULTURE.

ESTATE PRODUCTS COMMITTEE.

Minutes of the forty-sixth meeting of the Estate Products Committee of the Board of Agriculture held at the Head Office of the Department of Agriculture at 2-30 p.m. on Tuesday, November 12, 1929.

Present:—The Acting Director of Agriculture (Chairman), the Acting Mycologist, the Acting Entomologist, the Agricultural Chemist, the Hon. Mr. A. Mahadeva, Mr. S. Pararajasingham, Mudaliyar S.M.P. Vanderkoen, Messrs. T. B. Kobbekaduwa, R. P. Gaddum, A. T. Sydney Smith, A. W. Warburton-Gray, J. P. Blackmore, James W. Ferguson, G. O. Trevaldwyn, Dr. Roland V. Norris, Sir James Peiris, Sir Solomon Dias Bandaranaike, Messrs. Gordon Pyper, John A Coombe, A. W. Ruxton, E. C. Villiers, J. Sheridan-Patterson, G. B. Foote, J. Fergusson, N. D. S. Silva, Graham Pandittasekera, C. E. A. Dias, Chas. A. M. de Silva, A. W. Reid, F. H. Griffith, F. A. E. Price, J. D. Dunlop, T. E. H. O'Brien and Mr. L. Lord (Acting Secretary).

Visitors:—Messrs. N. K. Jardine, J. C. Haigh, Huntley Wilkinson, C. E. Seneviratne and W. G. Berry.

Letters or telegrams regretting their inability to attend were received from Messrs. Allen Coombe, G. C. Slater, H. L. de Mel, J. E. P. Rajapakse, C. C. du Pré Moore, G. R. de Zoysa, John Horsfall, Gate Mudaliyar A. E. Rajapakse, the Hon. Mr. D. H. Kotalawala, the Government Veterinary Surgeon, the Government Agent, N.P., and the Government Agent, S.P.

AGENDA ITEM 1.—CONFIRMATION OF MINUTES.

The minutes of the last meeting, which had been circulated to members, were taken as read and were confirmed.

AGENDA ITEM 2.—PROGRESS REPORT OF THE EXPERIMENT STATION PERADENIYA FOR THE MONTHS OF SEPTEMBER AND OCTOBER, 1929.

The report, which had been circulated to members, was reviewed by Mr. Lord. Mr. Gordon Pyper said that he had lately visited the Experiment Station and that he considered the pruning referred to in the report much too drastic, that recovery would be slow and that he apprehended many casualties. Mr. Lord replied that the method of pruning was the same as had been employed previously and that as the area was under experiments no change could be made without affecting the experiments. Mr. Ruxton stated that it would be advisable to consider altering the method of pruning as the results of the present experiments would not be applicable to modern estate practice. The Chairman suggested that the matter be brought up at the next meeting by which time Mr. Holland who had laid down the experiments would have resumed charge of the Experiment Station. This was approved by the meeting. In reply to Mr. Pyper, Mr. Lord stated that the pruning mixture consisted of 100 lb. basic slag and 60 lb. sulphate of potash, being the same as that used previously. Mr. Foote said that the list of Ceylon mother-trees being used at the Iriyagama Division did not include tree No. 6278 in field No. 4 of Waga Estate. This was a high-yielding tree which he thought ought to be included. The Chairman promised that inquiries should be made and pointed out that the list was

by no means final. Records of mother-trees were still being taken and would be examined by the Rubber Research Scheme. Mr. Pyper said that the drains in the soil erosion experiment plots were too steep and that it would be advisable to have plots treated in accordance with modern practice. The Chairman pointed out that when the experiment started the system of drains was similar to that in use on many tea estates. Methods were continually improving but it was impossible to be continually altering experiments. He agreed that other treatments were desirable in order to obtain more information on this very important subject but thought that the best method was to add to the number of plots if and as circumstances permitted. He promised to look into the matter with the Manager of the Experiment Station. Mr. Gaddum asked if there would be any restriction on the sale of bud-wood of the Malayan clones mentioned in the report. The Chairman replied that bud-wood of at least one Malayan clone had been procured subject to certain restrictions on future use. Speaking of the importation of bud-wood or budded stumps into Ceylon, Mr. Foote asked if the Director of Agriculture could arrange for there to be no delay in clearing shipments at Colombo. His last consignment had been held up at the Fumigatorium as the necessary documents had not been received. The Chairman undertook to look into the matter. The progress Report was then adopted.

AGENDA ITEM 3.—KALUTARA SNAIL.

The Chairman opened discussion by directing attention to the memorandum, which had been circulated, on the control of the Kalutara snail by the Ruddy Mongoose and by ducks. In the course of the discussion which followed Sir Solomon Dias Bandaranaike stated that the Red Crow was well known to eat the snail. Mr. Foote said that this bird came under the Vermin Act in India as it destroyed other birds' egg. Mr. Trevaldwyn thought that collecting the snail was successful but this view was opposed by Messrs. Foote and Sydney Smith. In reply to a question as to whether burying the snails collected would kill them Mr. Trevaldwyn replied that it would. Sir Solomon Dias Bandaranaike added that the snails should be covered with lime before burying. Mr. Ruxton asked if the bodies of the snails had any manurial value. Mr. Joachim replied that he had not made any analysis but that he thought they would be of some use. Referring to control by ducks Mr. Foote said that one difficulty would be to move the ducks from one part of the estate to another. The discussion was concluded by the Chairman who said that he would make inquiries from the Colombo Museum as to the desirability or otherwise of having the Ruddy Mongoose and the Red Crow protected.

AGENDA ITEM 4.—CHILAW COCONUT TRIAL GROUND.

The Chairman explained that this item of the agenda had been considered at their last meeting when it was decided to postpone further discussion until members had had the opportunity of studying the memoranda on the trials and on the proposed new experiments. The necessary papers had now been circulated. At the last meeting the Hon. Mr. Mahadeva had suggested that on the next agenda it should be stated that the question of continuation of the trials was to be decided. He wished to apologise for this having been inadvertently omitted. The Chairman stated that there were three possible courses open to them: one was to abandon the experiments, a second was to continue the present experiments and a third was to discontinue these and to lay down a new experiment on modern lines. He had been in communication lately with Mr. Martin, on whose estate the experiments were being conducted, and Mr. Martin was quite willing that they should abandon the present experiments and commence a new series, at the end of which he hoped the

Department would devote the money given for these trials to apply a general mixture for a few years in order to recondition the area used for the trials. Mr. Joachim had submitted certain proposals suggesting the lines of the new experiments, which would take from three to four years.

Mr. Mahadeva said that he had spoken to Mr. Martin, who was against the experiments being discontinued and had also remarked that the land had considerably depreciated as a result of the trials and that he felt he had a right to claim compensation in respect of the land. The Chairman said that some of the plots might have deteriorated and that Mr. Sheridan-Patterson could give exact information. Mr. Patterson stated that plot No. 12 which had been constantly disc-harrowed was an extremely bad case and that it was hardly fair to the estate to continue carrying out experiments which were going to lessen the value of the land. Dr. Norris asked what would be the relation between the Coconut Research Scheme and the new experiments. Were they to be conducted by the Department or would the Scheme take them over? The Chairman said they would always be in the hands of the Department because the money voted by the Legislative Council was departmental money entirely. However, he supposed there would be co-operation between the two bodies. Dr. Norris said that if the Coconut Research Scheme was to be concerned with these experiments it seemed rather unsound policy to lay down experiments which might last four or five years and thus tie the hands of the new Director by leaving him a legacy of this kind because it was possible that he would have other views. The Chairman remarked that the legacy would be the responsibility of the Department of Agriculture. A general discussion then ensued which was entered into by Messrs. Sydney Smith, Dr. Norris, Mr. Joachim, Mr. Dias, Mr. Fergusson, and Mr. J. P. Blackmore after which it was decided that, in view of the unsatisfactoriness of the present experiments and the impossibility of obtaining reliable results from a new experiment owing to the residual effects of the old treatments, the old experiments should be discontinued and that a general mixture should be applied to the plots for a number of years to bring back the plots to a satisfactory level of fertility. Mr. Dias thought it would be found there was little difference between the yields of the plots before the experiments were started and the yields at the present time and suggested that the Chairman should have the figures worked out. The Chairman agreed to arrange with Mr. Martin the particulars of the application of the general mixture.

AGENDA ITEM 5.—TEA TORTRIX REGULATIONS.

The Chairman invited Mr. Jardine to review the returns which had been tabled. Mr. Jardine stated that along with the statement of egg masses collected during the period July-September 1929 he had prepared a summary of the results of the quarterly periods for the last two years in order that members could see the general position, progress and seasonal fluctuations. He wished to remind members of the Committee that it was decided at the commencement of the Tortrix campaign to concentrate only on those districts which were known to be badly attacked, namely, Ambegamuwa, Dickoya, Lower Dickoya, Maskeliya and Dimbula. It was very difficult to submit figures which were brief and at the same time comprehensive. In considering the figures he recommended a comparative study of the returns for similar periods, taking into account also the rainfall. It would be seen that certain estates had reported no Tortrix at all. He trusted that they would be able to judge from the records whether the measures adopted had done any good in the way of eradicating or even lessening Tortrix in those districts which were considered to be most seriously affected and added that the returns from all estates, and in particular those in the five chief Tortrix districts, were very encouraging. The percentage of returns

from Ambegamuwa was 82, from Dickoya 87, Lower Dickoya 94, Maskeliya, 99 and Dimbula 96. This had greatly facilitated the work of compiling figures. The Chairman asked Mr. Jardine if he could say definitely that collection of egg masses was effective in reducing tea Tortrix. Mr. Jardine said that it was impossible to give a definite answer but was of opinion that the regulations were of use and that they would be of help to the Tea Research Institute. The Chairman thought that the best course would be to leave the matter entirely in the hands of the planting districts concerned and abide by their decision as to whether they were in favour of the regulations being continued or not, in the latter case the regulations could be repealed.

Mr. G. O. Trevaldwyn said that, regarding the Dickoya districts of the 65 replies received, 49 were in favour of the continuation of the regulations and 16 against. He thought that the general feeling was in favour of the continuation of the regulations. He would like to see the investigation carried out on scientific lines with co-ordination between the collecting authority and the Tea Research Institute. Without this he was afraid the figures would be of no value.

The Chairman said that he had referred the matter to the Planters' Association and through it to the district associations. He had not had any information from the district associations yet, but he noticed, from the press, that there had been discussions on the subject by certain associations, indicating their desire to continue the regulations. The policy he would like to see adopted was the scientific investigation suggested by Mr. Trevaldwyn when the Entomologist to the Tea Research Institute arrived.

Dr. Norris thought it would be unfortunate if the regulations were withdrawn after only two years' trial, particularly as there had been abnormal climatic conditions this year. Mr. Villiers said that he could give no official pronouncement as to the views of the Planters' Association but believed that there was a general feeling in favour of continuing the regulations. Mr. Sydney Smith said the measures adopted had been beneficial and that he would like to see the trial continued for five years.

The meeting agreed to the Chairman's proposal that the regulations should be kept in force, if the district associations concerned wished them to be retained.

AGENDA ITEM 6.—ROOT DISEASE.

The Chairman drew attention to two papers which had been circulated to members, one of which was a summary of the discussion of root diseases at the Imperial Mycological Conference and the other a note on recent work on root diseases in Ceylon prepared by the Acting Mycologist.

There was no discussion and the Chairman concluded the meeting by stating that, if members desired it, the January 1930 meeting would be held at the Experiment Station, Peradeniya. This proposal was approved.

L. LORD,
Acting Secretary,
Estate Products Committee.

MATARA DISTRICT AGRICULTURAL COMMITTEE.

PROCEEDINGS of the 12th Meeting of the District Agricultural Committee held at the Kachcheri on the 19th November, 1929, at 2 p.m.

Attendance.—Present Mr. R. M. M. Worsley, C.C.S., in the chair and the following members: Messrs. W. C. Lester-Smith, Divisional Agricultural Officer, D. Samaraweera, E. J. Buultjens, W. R. C. Paul and R. C. Kannangara, and Mudaliyars W. A. Ameresekere, H. E. Wickremeratne, W. A. Wijesinghe, F. A. Wickremeratne and A. B. W. Jayasekera.

Minutes.—The minutes of the previous meeting held on 11th July, 1929, were confirmed.

Results of Competitions.—Tabled results of competitions for 1929.

Allocation of prizes to competitions for 1930.—Tabled letter No. D1268 of 22nd October, 1929, from the Director of Agriculture re allocation of Rs. 500/- for prizes for competitons for 1930.

COMPETITIONS FOR 1930.

It was decided that the garden competitions and the paddy competitions were of very little value and that they should be discontinued.

A proposal made by the Mudaliyar, Gangaboda Pattu, that there should be competitions for home gardens for school children was rejected, as such competitions are already in existence, organized by the Agricultural Department and paid for from another vote. The D.A.O. undertook to consider the wider extension of these competitions.

It was decided that separate competitions should be held this year for each pattu or korale for the best paddy lot, and that entries should be restricted to plots on which manure was used. Three prizes of Rs. 50/-, Rs. 20/-, and Rs. 10/- to be offered for each Chief Headman's division. But the Committee reserves the right to reduce or cancel any of these prizes if the number or standard of the entries is not satisfactory.

The D.A.O. undertook to draft the necessary leaflets advertising the competitions

JUDGES.

The following judges were appointed to associate with the D.A.O. in judging the competitions:—

1.	Four Gravets	The Mudaliyar	and Mr. G. H. Altendorff.
2.	Weligam Korale ...	do	and Mr. Samaraweera.
3.	Morawak Korale ...	do	and Mr. R. C. Kannangara.
4.	Wellaboda Pattu ...	do	and Mr. Altendorff.
5.	Gangaboda Pattu ...	do	and Mr. Altendorff.
6.	Kandaboda Pattu ...	do	and Mr. Altendorff.

VOTE OF APPRECIATION.

A vote of appreciation of the services of Mr. Lester-Smith, the D.A.O., was proposed by the Chairman, seconded by Mr. Samaraweera and was unanimously passed.

WILLIE AMARASEKERA,
Hony. Secretary.

Matara, 19th November, 1929.

DEPARTMENTAL NOTES.

PADDY, COTTON AND VEGETABLE CULTIVATION COMPETITIONS IN MANNAR DISTRICT.

PADDY MANURING COMPETITION, MANNAR DISTRICT, 1928-29.

A paddy manuring competition was held in Mantai North, Mantai South, Nanaddan East and Nanaddan West during Kalapokam season, 1928-29, with 70 entries. Some cultivators transplanted their fields, while the rest applied green and farmyard manure. The Agricultural Instructor of the district helped the cultivators with advice. The following were the prize-winners :—

MANTAI SOUTH.

1.	Marisal Lawrence of Mathalaikatty	...	Rs. 15·00
2.	Philippu Thevar Gaspar of Nilasenai	...	,, 10·00

MANTAI NORTH.

1.	A Philippupillai of Kannaddi	...	,, 15·00
2.	Arokkiam Croos of Adampan	...	,, 10·00

NANADDAN EAST.

1.	P. Jeremiah of Murunkan	...	,, 15·00
2.	A. Seemampillai of Murunkan	...	,, 10·00

NANADDAN WEST.

1.	Marisal Manavalpillai of Nanaddan	...	,, 15·00
2.	N. Manavalpillai of Nanaddan	...	,, 10·00

GARDEN COMPETITION, MANNAR DISTRICT, 1928-29.

Competitons were held in Mantai North, Mantai South, Nanaddan East, and Nanaddan West during Kalapokam season, 1928-29 for vegetable growing with 63 entrants, fifteen of whom cultivated over 10 varieties of vegetables. The following were adjudged winners :—

MANTAI NORTH.

1.	Visenthi Pirakasam of Kattankulam	...	Rs. 18·00
2.	Bernard Arokkiam of Adampan	...	,, 12·00
3.	Aramukan Mathathampi of Papamoddai	...	,, 6·25

MANTAI SOUTH.

1.	M. Santhan of Pathukomam	...	,, 18·00
2.	B. Kanagasabai of Periyanavatkulam	...	,, 12·00
3.	A. Perusinavalai Manuel of Nilasenai	...	,, 6·25

NANADDAN EAST.

1.	Phillippu Mikkel of Murunkan	...	,, 18·00
2.	Makhosa Veranadatha of Parikarikandal	...	,, 12·00
3.	Anthoni Visuvasam of Chundikkuli	...	,, 6·25

NANADDAN WEST.

1.	Benjaminparikari Philippupillai of Suriyathevar Kaddaikkadu	...	,, 18·00
2.	M. Gabriel of Nanaddan	...	,, 12·00
3.	C. M. Mariyampillai of Nanaddam	...	,, 6·25

COTTON CULTIVATION COMPETITION IN VANNI VILLAGES OF MANTAI DIVISION, MANNAR DISTRICT, 1928-29.

A cotton cultivation competition was held in the Vanni villages of Mantai Division during 1928-29. The Cambodia variety of cotton was cultivated on chena lands. The judging was carried out by the Agricultural Instructor of the District and the following were adjudged winners :—

1.	A. Kanthappa of Palampiddi	...	Rs. 15·00
2.	K. Kanapathi of Palampiddi	...	,, 10·00
3.	S. M. Nellinathapillai of Iranaillapaikulam	...	,, 5·00

PURE-LINE PADDY CULTIVATION COMPETITION, TRINCOMALIE DISTRICT, 1928-29.

A paddy cultivation competition was held in Tamblegam during the Pinmari season of 1929.

Ten cultivators entered the competition. The Agricultural Instructor, Trincomalie, visited the fields and gave all necessary advice and carried out the preliminary judging and the final judging was done by the Vanniah assisted by a prominent agriculturist and the Agricultural Instructor. The heavy rains during cultivation and sowing time were a setback to the competition, but the prize-winners displayed keenness in their attempts to maintain their fields from weeds.

The following were adjudged winners :—

1.	P. Nalliah of Kadampai	...	Rs. 30·00
2.	Kathiramathamby of Kovilkudyirrappa	...	,, 20·00
3.	S. Kaliappu of Paddimeda	...	,, 10·00

VEGETABLE GARDEN COMPETITION, BATTICALOA DISTRICT.

A vegetable garden competition was organised by the Food Products Committee, Batticaloa, for the encouragement of increased cultivation of vegetables in the district. The competition was very successful.

In Wewegam, Bintenne and Panama Pattus where chena products only are generally cultivated, the competition induced the villagers to grow vegetables.

The following were adjudged winners :—

BINTENNE PATTU.

1.	Appuhamy Kandiah of Dambadeniya	...	Rs. 20·00
2.	H. Mohamadu of Harasgala	...	,, 10·00

ERAUR KORALAI

1.	S. Rasiah of Sengalady.	...	,, 20·00
2.	T. Thamothoram of Sengalady	...	,, 15·00
3.	N. Sabapathipillai of Eraur	...	,, 10·00

MANMUNAI NORTH

1.	K. Kandaih of Saturukendan	...	,, 20·00
2.	G. Poopalapillai of Kokavil	...	,, 15·00
3.	S. Muttaih of Saturukendan	...	,, 10·00

MANMUNAI SOUTH AND ERUVIL PORATIVU.

1.	V. Kandapody of Kodamadu	...	,, 20·00
2.	P. Alagipody of Magilarmunai	...	,, 15·00
3.	A. Mylipody of Magilarmunai	...	,, 10·00

KARAVAGU PATTU.

1.	K. Kandiah of Kalmunai	...	,, 20·00
2.	A. Vykalipedy of Periyanulamunai	...	,, 15·00
3.	V. Gnanamuttu of Periyanulamunai	...	,, 10·00

AKKARAIPATTU.

1.	K. M. Kalimeepam of Kalavil	...	,, 20·00
2.	K. Sinnapillai of Kalavil	...	,, 15·00
3.	S. Nagamanai of Addalachhenai	...	,, 10·00

PANAMA.

1.	A. S. Methir of Pottuvil	...	,, 20·00
2.	S. Muhallam Meera Lebbe of Pottuvil	...	,, 15·00
3.	R. Cassim Bawa of Potuvil	...	,, 10·00

WEWEGAMA PATTU.

1.	B. Gamandi of Thottama	...	,, 20·00
2.	D. M. Ratnayake of Dammana	...	,, 10·00

VEGETABLE GARDEN COMPETITIONS, GALBODA AND KINIGODA KORALES, 1928-29.

A large number of entries were received for the above competitions and great keenness was shown by the competitors. The Agricultural Instructor, Kegalle, visited the gardens on several occasions and gave the cultivators useful hints on plantain cultivation. The final judging was done by the Divisional Agricultural Officer, Central. In the case of the competition held in Kinigoda Korale, the first four gardens gained equal points and have been awarded equal prizes.

The following were adjudged prize-winners :—

GALBODA KORALE.

1.	Mohottalage Bisomenika of Udapamunuwa ...	Rs. 50·00
2.	M. Ranasinghe Vedarala of Badulupitiya ...	,, 40·00
3.	Rankotpedige Andiya of Dunugama ...	,, 20·00
4.	Warasampedige Motha of Diwala ...	,, 15·00

KINIGODA KORALE.

D. A. E. Abeywardane of Andirimada ...	Rs. 31·25
M. D. S. Gunawardane of Andirimada ...	,, 31·25
Wattuwa, Vidane Duraya of Diyagama ...	,, 31·25
R. Punchiappuhamy of Yatapawala ...	,, 31·25

REVIEW.

SISAL.*

PRODUCTION AND PREPARATION.

THIS book edited by H. Hamel Smith, the editor of *Tropical Life,* and published by John Bale, Sons & Danielsson, Ltd., will be found of value and interest to all engaged in the sisal industry. In it the author has collected up-to-date information on methods of production and preparation of the species of *Agave* known to commerce as sisal hemp and of other fibres.

The history and botany of the *Agave* fibre plants are discussed, and, in addition to a description of their growth in the field and of the equipment in use for their preparation in the factory, carefully compiled figures of both capital and revenue costs in the countries of production are given. The difficulty of the disposal of sisal waste is emphasised, and the necessity for investigation into the possibilities of its utilisation to give useful bye-products is indicated. The question of the employment of labour-saving appliances in the field and the prospects before suitable catch-cropping methods are, we consider, not sufficiently dealt with in view of their undoubted importance in the economical management of a sisal plantation.

One is left with the impression that sisal production is a matter best suited to company organization having at its disposal large reserves of capital for the development of the large areas of land required to maintain the scale of production demanded by even a single factory unit such as a large Robey decorticator.

Ceylon's most important venture in sisal production, like many pioneering efforts in this country, ended in financial failure, but we think that with the knowledge there gained there is a future for large-scale production in the island if land can be made available in the dry zones. Sisal planting as a village activity for small-holders has, we consider, distinct possibilities, but the chances of the successful development of the industry would appear to depend largely upon the evolution of a satisfactory type of portable decorticator.

The sisal industry is one which would benefit greatly from an interchange of ideas and experience, by the evolution of standardised methods and of a standardised costing system, and by the results of scientific research, and it is to be hoped that the world-wide Sisal Planters' Association, to the formation of which a chapter of the book is devoted, will shortly be created.—G. Harbord.

* Sisal: Production and Preparation, by H. Hamel Smith. London: John Bale, Sons & Danielsson, Ltd. 21 shillings.

ANIMAL DISEASE RETURN FOR THE MONTH ENDED 31st DECEMBER, 1929.

Province, &c.	Disease	No. of Cases up to date since Jan. 1st 1929	Fresh Cases	Recoveries	Deaths	Balance Ill	No. Shot
Western	Rinderpest	3452	60	562	2544	6	340
	Foot-and-mouth disease	902	28	898	4	...	...
	Anthrax	...	...	...	...	...	...
	Piroplasmosis	2	...	1	1	...	...
	Rabies. (Dogs)	3	2	...	...	...	3
Colombo Municipality	Rinderpest	1811	...	243	1568	...	...
	Foot-and-mouth disease	308	...	294	14	...	...
	Anthrax	3	...	...	3	...	...
	Rabies (Dogs)	36	...	...	...	...	36
	Haemorrhagic septicaemia	6	...	...	6	...	...
	Black Quarter	2	...	...	2	...	...
Cattle Quarantine Station	Rinderpest	51	...	32	19	...	...
	Foot-and-mouth disease	42	..	42	...	...	...
	Anthrax (Goats)	204*	19	...	204	...	...
Central	Rinderpest	46	...	1	44	...	1
	Foot-and-mouth disease	1202	10	1200	2	...	...
	Anthrax (Goats)	2	...	...	2	...	...
	Haemorrhagic septicaemia	3	...	...	3	...	...
	Rabies (Dogs)	32	1	...	26	...	6
Southern	Rinderpest	85	2	19	58	...	8
	Foot-and-mouth disease	2014	...	1958	56	...	...
	Anthrax	...	...	...	...	...	...
Northern	Rinderpest	4	...	3	...	...	1
	Foot-and-mouth disease	651	494	87	70	494	...
	Anthrax	...	...	...	...	...	...
Eastern	Rinderpest	...	..	...	...	...	...
	Foot-and-mouth disease	8006	..	7851	155	...	...
	Anthrax	...	...	...	...	...	...
North-Western	Rinderpest	4381	938	142	2041	18	2180
	Foot-and-mouth disease	147	...	147	...	...	..
	Anthrax	...	...	...	..	...	...
	Piroplasmosis	5	...	5	...	...	...
North-Central	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	2085	827	1696	57	332	...
	Anthrax	...	...	...	...	...	...
Uva	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	419	23	417	1	...	1
	Anthrax	...	...	...	...	...	...
	Haemorrhagic septicaemia	1	...	...	1	...	...
Sabaragamuwa	Rinderpest	500	18	45	451	...	4
	Foot-and-mouth disease	4904	231	4544	115	245	...
	Anthrax	...	...	...	...	...	...
	Haemorrhagic septicaemia	14	...	1	13	...	...

* One case in a buffalo

G. V. S. Office,
Colombo, 11th January, 1930.

G. W. STURGESS,
Government Veterinary Surgeon.

METEOROLOGICAL.

DECEMBER, 1929.

Station	Temperature		Mean Humidity	Mean amount of Cloud 0=clear 10=overcast	Mean Wind Direction during Month	Daily Mean Velocity	Rainfall		
	Mean Daily Shade	Difference from Average					Amount	No. of Rainy Days	Difference from Average
	°	°	%			Miles	Inches		Inches
Colombo Observatory	78·2	—0·4	80	6·2	N	101	5·01	19	— 0·45
Puttalam	77·4	+0·2	82	5·6	NNE	77	4·73	12	— 1·47
Mannar	78·4	0	82	7·0	NNE	179	6·94	18	— 0·77
Jaffna	77·4	+0·3	83	8·0	NE	50	11·82	15	+ 1·53
Trincomalee	77·2	—0·7	86	6·4	NNE	118	10·16	21	— 3·81
Batticaloa	77·4	—0·6	87	7·1	NNW	200	17·32	21	+ 0·79
Hambantota	78·2	—0·4	83	5·4	NE	274	8·64	17	+ 3·36
Galle	78·0	—0·5	86	6·4	Var:	104	8·59	16	+ 1·88
Ratnapura	79·5	0	78	6·3	—	—	7·20	16	— 1·76
Anu'pura	76·2	—0·8	86	7·6	—	—	4·51	17	— 4·15
Kurunegala	78·2	0	79	7·1	—	—	3·85	15	— 3·24
Kandy	71·3	—0·2	80	6·2	—	—	7·43	12	— 1·48
Badulla	70·8	+0·4	86	6·8	—	—	13·17	18	+ 0·96
Diyatalawa	64·6	—0·3	84	7·1	—	—	11·22	19	+ 3·42
Hakgala	59·8	—0·1	87	5·9	—	—	17·10	25	+ 3·72
N'Eliya	59·8	—0·2	82	6·8	—	—	10·51	19	+ 2·17

Rain was fairly widespread during the first half of December but there was very little from the 14th to 21st, after which it was again general till the end of the month. The totals for the month were pretty consistently above average in the southern half of the Eastern Province, in Uva, and the south east quarter of the Central Province. Variations above and below average were about equally divided in the Northern, Southern, and Western provinces. Deficits predominated in Sabaragamuwa and were the general rule in the N.C.P., N.W.P., and the northern halves of the E.P. and E.P.

Depressional activity was not very marked and a rough description of the general distribution of rain can be given by saying that it suggested the normal distribution of January rather than that of December.

The highest totals were St. Martin's (Upper) 37·33 inches, Hendon 34·68, and Uva Estate 32·42 inches, while the biggest excesses above average were in the Arugam Bay district. Only three stations recorded less than two inches.

Potuville, with 9·1 in. on the 23rd, had the highest fall in 24 hours, but falls of over 6 in. were also recorded on that day at Poonagalla, Tissamaharama, Uduvila, Uva Estate and Yala as well as at Bandaragama on the 4th.

A. J. BAMFORD,
Supdt., Observatory.